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The Effects of Various Gas Atmospheres on the Oxidation of Coal Mine Pyrites

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27 Abstract

~~A number of~~ Experiments up to 150 days in length were conducted to study the acid production rate of coal mine pyrites under various gas atmospheres. The gas atmospheres studied were air, nitrogen, methane, and carbon dioxide. The lower limits of the oxidation process were studied by introducing small amounts of oxygen along with the inert blanketing gas and by studying the effects of deaerated versus air saturated feedwater. Acid production was ~~found to be~~ proportional to the available oxygen partial pressure.

The acid parameters monitored continued to change and had not completely reached a steady state by the termination of the work. The acid production of nitrogen blanketed pyrite decreased to less than 1% of that of identical columns under air atmosphere. Nitrogen and methane gases were equally effective in reducing acid production. Both of these gases were slightly more effective than carbon dioxide. A large amount of detailed experimental data is presented. ~~(EPA abstract)~~

~~This report was submitted in fulfillment of Contract No. 14-12-877 between the Environmental Protection Agency, Water Quality Office and Cyrus Wm. Rice Division - NUS Corporation.~~

Abstractor

Institution Cyrus Wm. Rice Division-NUS Corporation

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The Effects of Various Gas Atmospheres on the Oxidation of Coal Mine Pyrites

by

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for the

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ABSTRACT

A number of experiments up to 150 days in length were conducted to study the acid production rate of coal mine pyrites under various gas atmospheres. The gas atmospheres studied were air, nitrogen, methane, and carbon dioxide. The lower limits of the oxidation process were studied by introducing small amounts of oxygen along with the inert blanketing gas and by studying the effects of deaerated versus air saturated feedwater. Acid production was found to be proportional to the available oxygen partial pressure.

The acid parameters monitored continued to change and had not completely reached a steady state by the termination of the work. The acid production of nitrogen blanketed pyrite decreased to less than 1% of that of identical columns under an air atmosphere. Nitrogen and methane gases were equally effective in reducing acid production. Both of gases were slightly more effective than carbon dioxide. A large amount of detailed experimental data is presented.

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Key Words: Acid mine water, inert gas blanketing of coal mines, pyrite oxidation, acid production in coal mines, pyrite, water pollution control, water quality, and acid mine drainage.

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Comments From The Project Officer

It is profitable for the reader to compare the results from this project with those given in project 14010 DKN 11/70. This latter work, performed by Dr. R.A. Baker, at Mellon Institute, describes some similar, but not identical experiments.

A comparison of column 2, of the Rice study (page 52) and the Mellon Institute experiments (see page 58 of the former work) indicates a very close correlation. Both experiments provide a pyrite, exposed to water which was saturated with air. The effluent concentrations are listed below:

	Rice	Mellon
pH	4-5	4.1
iron (mg/l)	0.8-0.9	1.3
acidity (mg/l)	6-8	7
sulfate (mg/l)	6*	7

* varies from 1 to 29 but the average is 6.

The close correlation between two independent studies lends credence to the conclusions expressed in this report.

SECTION I

CONCLUSIONS

The following conclusions were drawn based on the results obtained during this study:

1. The acid drainage from coal mine pyrite, in terms of iron, sulfate, acidity and conductivity is proportional to the oxygen partial pressure in the gas phase in contact with the pyrite.

2. Nitrogen and methane are superior to carbon dioxide as blanketing gases in reducing the acid production from coal associated pyrites.

3. Acid production by pyrite under an inert gas atmosphere is affected by the dissolved oxygen content of the feedwater.

4. Within the range of gas and water flow rates studied, the amount of water available did not influence the rate of oxidation of pyrite

5. Inert gas blanketing of coal mine pyrites is an effective method of reducing pyrite oxidation.

6. The rate of change of acid production of pyrite as a function of time appears to be influenced by the history of the pyrite particle prior to its exposure to an inert atmosphere. This can be seen by comparing Figures XIX and XX with each other.

SECTION II

RECOMMENDATIONS

This study was limited to laboratory investigations on the effects of various gas atmospheres on coal mine pyrite oxidation. A practical application of the findings of this study would be full scale testing in an actual abandoned deep mine.

In such a study, inert gas blanketing could be accomplished by the use of a fuel-fired inert gas generator. Preliminary investigations presently underway at a small drift mine in southwestern Pennsylvania indicate that the gas requirements to pressurize this mine may be economically favorable for the prevention of acid mine drainage over conventional treatment methods. The results of this laboratory study indicate that the discharge from such a test mine under an inert gas atmosphere would be reduced to essentially groundwater limits while most conventional treatment methods, on the other hand, produce a rather low quality effluent.

In view of the possible advantages of such a preventative program, it is recommended that field testing be carried out.

Another area in which the information, techniques, and equipment used in this study could be applied is in the prediction of the relative polluting potential of new mining operations. This study has shown that the pounds of acid produced per unit of time is relatively independent of the water flow rate (over the range studied).

Samples of pyritic material from existing mines could be collected along with water samples of the discharge from the mine. The pyritic samples could then be subjected to a standardized column test and the quality of the effluent from the column correlated with the discharge from the mine. If a correlation between the discharge from the mine, and the discharge for the column could be developed, this data could be used to predict the relative pollution potential of future mines by subjecting core samples from the new areas to the same standard column test. The data could also be used in evaluating the pollution potential of highway cuts through coal seams, and other similar earth moving operations where pyritic material may be exposed.

SECTION III

INTRODUCTION

The formation of iron salts and sulfuric acid by the oxidation of pyrites is the major source of pollution from coal mining in the Eastern and Mid-Atlantic States. Pyrites, which are minerals containing sulfide, generally occur in association with various minerals and ores; such as coal, copper, gold, sulfur, etc. The mining of these minerals and ores exposes the pyritic materials which subsequently oxidize in the presence of moisture and air to form sulfuric acid and metallic sulfates. Where coal is mined these chemicals then dissolve in ground or surface waters to form dilute solutions of sulfuric acid and iron sulfate commonly known as "acid mine drainage." It has been estimated ① that more than 5,000 miles of streams and 13,000 acres of ponds in Pennsylvania, Ohio, Maryland, West Virginia, Kentucky, Tennessee, and Alabama have been polluted with coal mine drainage. The total mine drainage discharge has been estimated ② at more than 3.2 million tons of acid per year.

The chemical reaction

$$2\ FeS_2 + 7\ O_2 + 2\ H_2O \longrightarrow 2\ FeSO_4 + 2\ H_2SO_4$$

generally describes the oxidation reaction of pyrite. In studying the chemical reactions that take place, it is obvious that the exclusion of oxygen at the reactive pyritic sites should prevent the basic acid production reaction from occurring. Leitch ③ proposed air sealing of underground mines as a solution to the problem as early as 1927. This preventative technique was widely employed by the Works Progress Administration under the direction of the United States Public Health Service during the 1930's. It has been estimated that more than 20,000 air and water seals ④ were constructed by this Administration in order to prevent the discharge of acid mine drainage. The effectiveness of this sealing was not systematically evaluated and there is little factual information on the success of the program, however, the information available indicates a substantial reduction in acid production.

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Studies conducted by K. S. Shumate ⑤ and S. A. Bealey ⑥ have documented this theory on the reduction or prevention of acid formation in deep mines by the reduction of oxygen.

Laboratory studies by S. A. Braley ⑦ W. E. Bell ⑧ have further demonstrated that acid production can be controlled by the exclusion of oxygen, and that acid production will immediately start if air is admitted and will terminate shortly after the air introduction ceases.

Based on previous work, it is evident that if the atmosphere in abandoned deep mines could be maintained in an inert condition; that is, free from oxygen, the formation of acid by the oxidation process would be stopped and the production of acid mine drainage effectively eliminated. As has been pointed out, acid production will be induced as oxygen comes in contact with the pyritic material; however, the lower limits of the oxidation process have not been determined. The overall objective of this project was to determine the effect of various gas atmospheres on the oxidation of coal mine pyrite so that guidelines for field application of this technique can be set.

Specifically, this study was designed to answer the following questions:

1. How does the inclusion of small amounts of oxygen, along with a blanketing gas, effect pyrite oxidation?

2. What is the effect of air saturated versus deaerated water on pyrite under•the same atmosphere?

3. Will changing from an air to an inert gas atmosphere alter the production of acid by pyrite?

4. What part does water flow play in pyrite oxidation?

5. Would a carbon dioxide blanket be reactive with pyrite?

6. If pyrite under a carbon dioxide blanket is nonreactive, will small amounts of oxygen in the gas blanket have any effect?

7. If carbon dioxide is reactive, would the introduction of 90% nitrogen in place of carbon dioxide decrease the reaction.

8. How long does it require for a bed of coal mine pyrite under dynamic water and gas flow conditions to reach a steady state of acid production under different gas blankets?

9. What happens to chemical species such as iron, sulfate, aluminum, magnesium, calcium and manganese?

The experimental approach used in this study involved loading insulated glass columns with pyrite and trickling deionized water through the columns while controlling the gaseous atmospheres.

The acid production of the various atmospheres were studied by daily analysis of the effluent water quality of each column.

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SECTION IV

COLUMN DESIGN

Nine (9) pyrex glass columns, each 6' x 4" I.D., were vertically mounted on a test rack and outfitted with separate inlet gas and water tubes at the top and a common gas-water exit tube at the bottom for each column. Initially, all columns were outfitted with inlet water and outlet gas tubes at the top and inlet gas and outlet water tubes at the bottom. The gas and water exited at opposite ends to produce countercurrent flow. After 24 hours of operation it was observed that shallow flooding was occurring in the columns; to eliminate this situation, the inlet gases were introduced at the top of each column and a common outlet was provided at the bottom to produce cocurrent downward flow. Effluent gas and water separation took place in the first effluent water trap. Upon separation, gases were passed through a second water trap designed to prevent atmospheric air from entering the columns as well as to set the total column back pressure at about 12" of H_2O. The wastewater and gas disposal system is illustrated in Figures VII and XIII. Thick walled rubber tubing, stainless steel fittings and glass tubing were used for the various connections between columns and water traps to eliminate corrosion and the possibility of oxygen diffusion into the columns. The exterior support rack was arranged so that the discharge line from each column was approximately one foot from the floor. The overall column arrangement and associated hardware can be seen in Figures I and XVI.

The water flow rate to each column was controlled through polyethylene capillary tubing encased in aluminum tubing and fed from a common manifold. Except for programmed changes to Column No. 7, water flow rate into the columns was controlled at approximately 8.5 ml/minute. The common water source was deionized Pittsburgh tap water, deaerated, and dechlorinated by passage through the deaerator shown in Figures IX and XIV. After deaeration, the water was chilled and then passed through a second deionizer and

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distributed to each column (See Figure VIII). The second deionization was used to "polish" the water to insure its quality. The only exception to the exclusive use of deaerated feedwater was the use of air saturated water in Column No. 2, Phase II. A schematic arrangement of the aerated feedwater system is shown in Figure X. Each column was wrapped with fifty feet of 3/8" I.D. polyethylene tubing followed by fiberglass insulation (See Figure XV). Water was circulated from a chiller unit through the tubing in order to maintain a column temperature of approximately 55°F (the approximate year-round temperature in deep coal mines in the Pennsylvania area).

Inlet gas flows were controlled by a combination of regulators, valves and rotameters (See Figure XI). Gas flow rates to the various columns were adjusted to between 30 and 50 cc/minute. A "T" fitting was placed in both the inlet and outlet gas lines to permit monitoring of gas quality throughout the project. A schematic arrangement of a typical pyrite column assembly is shown in Figure II and the associated hardware is shown in Figures III, IV, V and VI.

The pyritic material used in this study was obtained from the Shawville Power Station of the Pennsylvania Electric Company, near Clearfield, Pennsylvania. This material was rejected at the coal crusher, and is believed to have been originally taken from strip mining operation in the Lower Kittanning Seam. The material was crushed and sized to a size of 3/8"-5/8". Each column was charged with 45 pounds of pyrite. A representative sample of the pyritic material was examined by X-ray diffraction. Iron pyrites, FeS_2, was identified as the principal crystalline component (the intensity of the pyrite pattern indicated that probably at least 75% of the sample was pyrite). Based on this analysis the total available iron present in each column was approximately 15.7 pounds. A portion of the sample was heated to about 500° overnight to convert it to the oxide form. The weight loss was 38.06%. A more detailed analysis of the pyrite is shown in Table III.

SECTION V

COLUMN OPERATION

The study was divided into two phases, each phase lasting approximately 75 days. Table I summarizes the column-gas-water flow data used in the project. As indicated, two columns were operated as control columns; Column No. 3 was operated in a nitrogen atmosphere and Column No. 6 in an air atmosphere throughout both phases of the study.

The lower limits of the oxidation process were investigated by introducing small amounts of oxygen along with the blanketing gas. Daily effluent water samples were collected and analyzed for pH, conductivity, total iron, hot phenolphtalein acidity and sulfate; influent samples were analyzed daily for pH and conductivity and spot checks were made of the hot phenolphthalein acidity and dissolved oxygen (See Tables XVI through XXXVl). Weekly water samples were analyzed for aluminum, manganese, calcium, magnesium and ferric iron (See Tables XXXVII through XLV. Tables XVI through XLIX are published separately as Volume II.

Initial startup of all columns was begun by flooding the columns with deionized water to displace all air. The gas used in each particular column was then used to displace the water and normal operations were started. The various gases and gas mixtures used were supplied by commercial sources (See Table IV for analyses). The initial gas flow rates were set at approximately 10 cc/minute and water flow rates were controlled by calibrated polyethylene capillary tubing at 8.5 ml/minute. Frequent monitoring of the influent and effluent gases during the first several days of operation indicated that there was a noticeable oxygen consumption in the four columns operating with an air atmosphere, (discussed further under results). To insure an adequate oxygen supply for the oxidation reaction, gas flow rates were increased to 45 cc/minute in all columns. Generally this flow rate was maintained throughout the study however, the inavailability of some gases necessitated a decrease in the gas flow to several columns later in the study (refer to Table II).

As previously mentioned, the quality of the feedwater to all columns was controlled by a second "polishing" deionization and the mean temperature of the column atmospheres was regulated at 55°F to simulate actual mine conditions. Feedwater analyses can be seen in Table XXVII.

The role of water flow rate on pyrite oxidation was studied by varying the water flow rate in an air blanketed column in Phase I and the same column in a nitrogen atmosphere in Phase II (See Table II).

Aerated water was used in Phase II on Column No. 2 in order to determine the effects of air saturated versus deaerated water on acid production under the same atmosphere (See Table XXXVI for Column No. 2 influent and effluent dissolved oxygen concentrations).

The total iron leached out in an air atmosphere for the entire 149 days of operation was 129.5 grams or less than 1.90% of the total available iron. The total iron removed under a nitrogen atmosphere for the same period of time was less than 0.085% of the available iron.

A detailed log of the column operation is presented as Table XIII and graphic representation of the major parameters as a function of time is shown in Figures XXI through XXIX.

SECTION VI

RESULTS

Internal Consistency

The data obtained throughout this study was evaluated primarily by a statistical analysis of the variance between the total iron concentrations in the effluent water discharge from the various columns. The 1% level of significance was used as the predetermined rejection level in all cases. Total iron concentrations were chosen as the test parameter because of the relatively high degree of accuracy of this analysis (total iron was analyzed according to ASTM methods with a sensitivity of 0.1 ppm). Sulfate analyses made during this study were found to be much less reliable than the other parameters.

The sequence of operation followed in this study resulted in triplicate operation in Columns 1, 2, and 3 under a nitrogen atmosphere and in Columns 4, 5 and 6 under an air atmosphere in Phase I. In order to verify the internal consistency of the test results, the variance of total iron concentrations between the related columns was determined. The difference in the effluent between the three nitrogen columns was found to be negligible at the 1% level of significance (refer to Table V), therefore, Column 3 will be used as the basis for all further discussions regarding nitrogen blanketed pyrite since this was a control column and the operating conditions were not varied between Phase I and Phase II.

The effluent total iron concentration from the air columns was found to be significantly different. (See Table VII). Theoretically, the acid production from these three columns should have been the same since the pyrite bed and operating conditions were identical (corrections were made for differences in water flow rate). For the purpose of further discussions, Column 6 will be considered representative of an air blanketed pyrite column. Column 6 was chosen because it was operated as a control column without any departures from the planned procedure for the duration of the study.

Nitrogen Atmosphere

The log of the acid concentration in the effluent from a column under a nitrogen atmosphere was found to decrease linearly with the log of time. This effect is shown in Figure XIX. Conductivity and iron concentration were also found to fall off in essentially the same manner.

The actual iron sulfate and sulfuric acid generated under a nitrogen atmosphere during the course of this study represents an insignificant fraction of the total available. If one assumes a discharge of 8.5 ml/min with an average concentration of 3.17 ppm of Fe, 149 days of operation represents only 5.79 grams or 0.013 pounds of iron over that period of time. This is only about 0.08% of the total available iron in the pyrite column.

An analysis of the variance between nitrogen blanketed columns in Phase I and Phase II, based on effluent total iron concentrations, reveals that acid production was significantly lower in the columns that had been initially operated under an air atmosphere (See Table X). It is interesting to note that the shape of the curves for rate of fall off of concentration is also different for pyrite which had been operated under an air atmosphere and for the fresh pyrite with which the columns were packed. This can be seen by comparing Figures XIX and XX. It is possible that oxidation during air stage resulted in a partial blinding of the most active pyrite sites, thereby reducing the oxidation reaction in the second phase. Since only a small fraction of the available iron sulfate and sulfuric acid was actually generated the possibility of iron depletion under the air atmosphere can be ruled out. A visual observation of pyrite removed from the subject columns at the termination of this study seems to substantiate the theory of reduced active surface area due to blinding of the pyrite by oxidation products.

Air Atmosphere

The data obtained from daily analysis of the effluent water discharge from pyrite under an air atmosphere is shown in Figure XVIII.

As previously stated, the air atmosphere control column (Column 6) will be used as the basis for conclusions of air blanketed pyrite in this study. A cation-anion balance was made based on the average results for Column No. 6 for the period project day 111 through 132 in order to determine the accuracy of the analytical results (See Table XV). The calculated error was less than 8% indicating a relatively close agreement.

Acid production under an air atmosphere decreased rapidly during the first eight to ten days of operation and then started to climb very slowly for the rest of the operating period (See Figure XVIII). By a comparison of the analysis of variance between the periods project day 59 through 73 and project day 120 through 134 (See Table VIII), we can conclude that there was not a significant difference between the variances of effluent total iron concentrations for those periods and that the column had reached a state of equilibrium. This result does not agree with the data shown in Figure XVIII. An inspection of the means for the two periods shows the mean for the later period to be higher than the mean for the earlier period as shown in Figure XVIII. However, when the variability of the data is taken into account, the two means cannot be established as being different. The quality of the early discharge, in terms of acid, sulfate, total iron, and conductivity appears to be substantially worse than that of near steady state conditions at the end of the run. This is believed to be due to the leaching of oxidation products which had accumulated prior to column startup. This trend is evident in all cases (Phase I and Phase II) where the pyrite had been exposed to an oxidizing atmosphere prior to startup. Assuming an average daily discharge of 12.25 liters, 149 days of operation with an average discharge of 71 ppm Fe represents only 129.5 grams or 0.29 pounds of iron over that period of time. This is less than 1.9% of the total available iron in the pyrite column. If one assumes the same rate of production, that is, 0.29 pounds per 149 days, it would take approixmately 4 years of operation to leach all of the available iron from the column.

Methane and Carbon Dioxide Atmospheres

The acid production in the column blanketed with methane (Column 8) follows the same pattern as the columns blanketed with nitrogen gas (See Figure XIX). This is not the case with carbon dioxide (Column 9). As can be seen from Figure XIX the conductivity and iron in the effluent of the carbon dioxide column is not the same as the nitrogen and methane columns. However, the acidity of the carbon dioxide was the same as the others. This results from the fact that the acidity was measured by the hot phenolphthalein test. In this test dissolved gases do not contribute to the result. The conductivity was measured on the cold samples so the contribution to conductivity of the dissolved carbon dioxide began to become more significant as the concentration of non-gaseous dissolved matter decreased. This causes the conductivity curve for carbon dioxide to drift off to the right. The iron concentration in the effluent from the carbon dioxide column was found to fall off at a different rate from the nitrogen and methane columns. This is presumably caused by the formation of a small amount of iron carbonate.

An analysis of variance between the three nitrogen blanketed columns (1,2,3) in Phase I and the methane column (8) in Phase I shows a difference at the 5% level but not at the 1% level (See Table IX). The same analysis performed on the nitrogen column (4) and the methane column (5) in Phase II does not show a difference at either level of significance. This indicates that the performance of nitrogen and methane as blanketing gases are very nearly the same, with methane possibly being very slightly inferior to nitrogen.

An analysis of the variance between the methane column (3) in Phase I and the carbon dioxide column (9) in Phase I shows the carbon dioxide to be definitely inferior to methane (and by implication also inferior to nitrogen) as a blanketing gas (See Table XI).

Neither the nitrogen, the methane, nor the carbon dioxide blanketed columns had reached a steady state of acid production by the termination of the study. Iron, acidity, sulfate and conductivity continued to decrease at a very slow rate; it is believed that acid production would have reached undetectable values had the experiment been carried out for a longer period of time.

As has been noted previously, the rate of response of columns under a nitrogen atmosphere is much slower than columns under an air atmosphere. The time schedule of the experiment called for reducing the water flow rate to the nitrogen column about 25 days after the start of Phase II. However, the data shows that the iron concentration was still noticeably falling when the water flow rate was reduced. Therefore, there is no solid base against which to compare the effect of the change. For this reason, no similar conclusions can be drawn for changes in water flow on a nitrogen column, but the expected result would be the same.

Gas Mixtures

The lower limits of the oxidation process were studied in Phase II by introducing small amounts of oxygen along with the various blanketing gases. The oxygen concentrations of the primary carrier gases are shown in Table IV. The findings of this study are graphically illustrated in Figure XVII. While it has been already acknowledged that, statistically, acid production varies under different inert gas atmospheres, the gas mixtures have been compared on an equal basis in order to determine the effects of oxygen concentration. From the graphical analysis, it is apparent that acid production is clearly a function of the oxygen partial pressure in the carrier gas and that a decrease in oxygen will decrease the amount of acid formed.

It is difficult to determine how long it would take to reach a steady state of acid production under the subject atmospheres. An examination of the daily effluent water analyses seems to indicate a slight increase in acidic parameters throughout the study. Analyses may have been influenced on several occasions by exhaustion of the primary deionizer resin bed (See Table XIII). One can only speculate on the effect of this interference. The graphical representation (Figure XVII) of the data was made on the assumption that an equilibrium had been reached in these columns and that there were no significant interferences from the feedwater deionizer.

The almost perfect agreement of the actual points for acidity, and the straight line through them is striking.

Using the mean value reported for the period between project day 54 and 73, the total iron concentration in the nitrogen blanketed column had been reduced to 0.68% of the total iron concentration in the effluent of an air blanketed column; this is in comparison with 0.75% with methane and 1.3% with carbon dioxide.

Water Flow Versus Acid Production

The effects of water flow rate of pyrite oxidation were to be studied by decreasing the water flow to an air and a nitrogen blanketed column under approximate steady state conditions by 80% (See Tables XXIII and XXXIII for detailed data). The effect of this reduction on an air column was an immediate increase in the acid concentration of the effluent discharge. While this appears to be a substantial increase in acid production, a closer analysis shows that the weight rate of leaching under the two flow conditions is practically identical. The means and flow rates of air column No. 7 for the periods under study were:

Project Days	Iron Means	Flow Rate
36 - 46	62.8 ppm	8.5 ml/min.
56 - 66	315.8 ppm	1.8 ml/min.
81 - 91	72.4 ppm	8.5 ml/min.

The average iron concentration before and after the change in flow is 67.6 ppm. It can be seen that the weight rate if iron dischage is virtually uneffected by the change in water flow:

$$67.6 \times 8.5 = 574.6$$
$$315.8 \times 1.8 = 568.4$$

The difference between the above two weight rates is 1%. The average of the before and after value is used because the iron curve was still rising slowly at the time of the test.

Upon returning the water flow rate to normal in an air atmosphere, the iron concentration immediately returned to the levels which would have been expected if the change in flow rate had not occurred.

The points for carbon dioxide which do not fall on the curves occur at a very low value. As previously explained, this is believed to be caused by the contribution of the dissolved carbon dioxide in the water. The two points on the iron curve which are for carbon dioxide atmospheres are slightly above the curve also. This iron deviation for carbon dioxide as well as the conductivity deviation for carbon dioxide are exactly as would be predicted by the data shown in Figure XIX.

Analyses of the influent and effluent gases (See Tables XLVI through XLIX) indicate that not all of the available oxygen present in the influent gases reacted with the pyrite; this is presumably due to the relatively short contact time within the columns. In a typical air column with an air flow of 45 cc/min, approximately 19.35 grams of oxygen per day would be applied. The dissolved oxygen content of the effluent water of an air blanketed column was increased by approximately 7 ppm. This solubility reduces the available gaseous oxygen to 19.27 g/day. The average daily discharge water from a column operated under an air atmosphere contained 0.87 g/day of iron or 0.01566 moles of iron per day. Since one mole of iron reacts with 3.5 moles of oxygen, the oxygen reacting with the pyrite was approximately 1.74 g/day. This represents a calculated 9.1% reduction of the gaseous oxygen in the effluent gas. The actual oxygen reduction observed in the air column was 10.8%. The calculated error is 16% which may be due to an error in the gas sampling procedure, gas chromatograph sensitivity or effluent iron analyses. The calculated error for the results of the theoretical oxygen consumption versus actual oxygen consumption is approximately the same in the Column 1, Phase II (nitrogen + 0.5% oxygen) and in Column 9, Phase II (carbon dioxide + 1.07% oxygen) as in the air column. The error involved in the column blanketed by methane + 0.11% oxygen is considerably higher (38%); however, in considering the extremely low oxygen concentration being studied, a 38% error may well be the result of gas sampling error. Analyses of the influent and effluent gases of the inert gas blanketed columns indicated a trace amount of oxygen in the effluent gases for the first week of operation; oxygen was not detected in subsequent analyses.

Deaerated Versus Air Saturated Water

The results of the investigation of the effects of deaerated versus air saturated water can be seen by comparing the data in Tables XVII and XXIX. The dissolved oxygen content of the influent and effluent water is presented in Table XXXVI.

The test column (Column No. 2) was operated under a nitrogen atmosphere using deaerated water in Phase I and under the same atmospheres using air saturated water in Phase II. Acid production, in terms of sulfate, iron, acidity, and conductivity, increased slightly upon switching to an air saturated feedwater. While there is an obvious response to the use of air saturated feedwater, the effluent water quality does not appear to be significantly changed. Again, the questionable influence of the deionizer upsets throughout Phase II make it difficult to accurately assess whether or not an equilibrium had been established by the termination of the study. If we were to assume that steady state conditions had been established, the total iron concentration in the effluent water discharge was increased by 55% by the use of air saturated water. Although this appears to be a substantial increase in the total iron content, the discharge water still contains less than 1 ppm of iron.

The average daily iron discharge from a nitrogen blanketed column using air saturated feedwater was 0.86 mg/l of iron.

Based on Figure XVII this iron concentration in the effluent is equivalent to an oxygen concentration in the gas stream of 0.092% when using deaerated water.

The incoming nitrogen gas to the column contained 0.02% oxygen. The incoming water contained 8.5 ppm of dissolved oxygen. If this dissolved oxygen is converted back to an equivalent concentration and in the gas stream, it is equivalent to applying gas with 0.11% O_2 content and deaerated feedwater as was done with the other columns. The disagreement between the 0.092% oxygen calculated from the iron content of the effluent and the 0.11% oxygen content calculated from the input conditions is 16%. This is generally the same level of accuracy as has been found in other measurements. With only this very limited data as a guide, it must be concluded that only the total oxygen applied controls the oxidation of the pyrite, and that it makes no difference whether the oxygen is gaseous or dissolved in the water.

In summary, the following conclusions were drawn from the experimental data;

1. The rate of acid production, in terms of sulfate, iron, acidity, and conductivity, are directly proportional to the oxygen partial pressure.

2. Nitrogen and methane are slightly more effective than carbon dioxide as blanketing gases in reducing the acid production from coal mine pyrites. This is particularly true when dealing with low concentrations of iron, acidity, etc.

3. The performance of pyrite in production of acid seems to be influenced to some extent by its history prior to being tested for acid production.

4. Water flow rate did not affect the amount of iron leached from coal mine pyrites within the range of flow rates studied.

5. There is no difference in acid production between applying oxygen in the gaseous phase versus applying oxygen dissolved in the water phase.

SECTION VII

GLOSSARY

Analysis of Variance - The degree of dispersion of the results of two or more groups from their means.

Deaerator - Hot water heater used to remove the dissolved oxygen from the water supply.

Deionizer - Mixed-bed ion exchange resin used to polish the water supply.

Dispersion - Extent to which a collection of data spreads around its central tendency.

Equilibrium - A steady state or balance between opposing influences.

Level of Significance - The probability, given in percentages, that a statistical statement is invalid.

Mean - Average value.

Pyrite - A common mineral that is found in association with most coal seams and consists of iron disulfide.

Rejection Level - The tabulated value, corresponding to the level of significance and sample conditions, which is used as the basis for acceptance or rejection of the hypothesis. When the calculated value exceeds the tabulated value, th variance between the groups being studied is deemed significant.

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SECTION VIII

ACKNOWLEDGEMENTS

Mr. E. Dennis Escher, formerly of the Rice Division - NUS Corporation, assisted in the design, operation, and data evaluation of the work which was the basis for this report.

The pyrite used in this project was obtained through the cooperation of the management of the Shawville Station of the Pennsylvania Electric Corporation located near Clearfield, Pennsylvania.

The support of the project by the Water Quality Office of the Environmental Protection Agency and the help provided by Mr. Donald J. O'Bryan, Jr., Mr. Eugene Harris, Dr. James Shackelford, the Grant Project Officer and Ernst P. Hall, Chief of the Pollution Control Analysis Branch, is acknowledged with sincere thanks.

The primary investigators on this work were Joseph C. Troy and John D. Robins of the Cyrus Wm. Rice Division - NUS Corporation.

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SECTION IX

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SECTION X

APPENDIX

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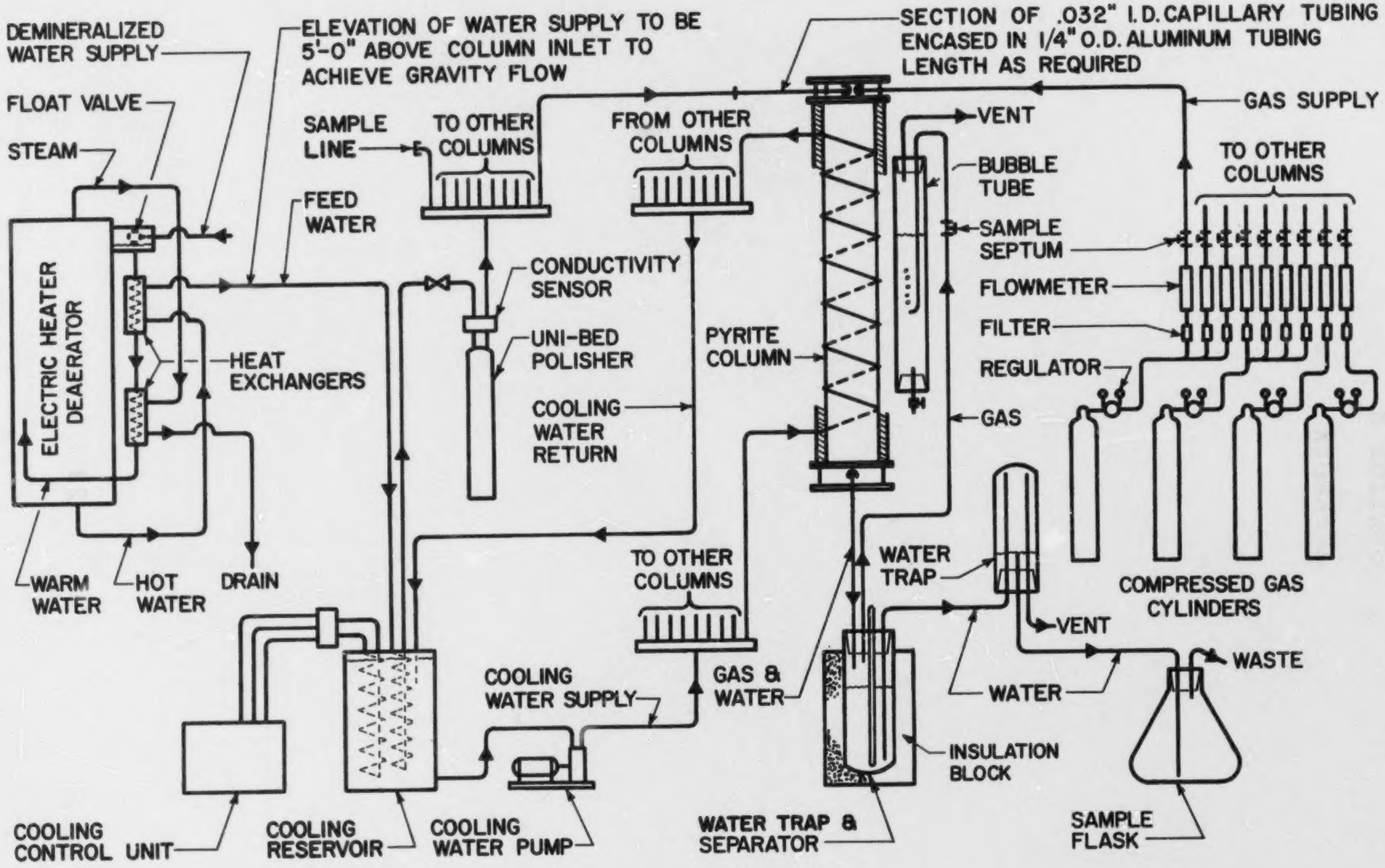
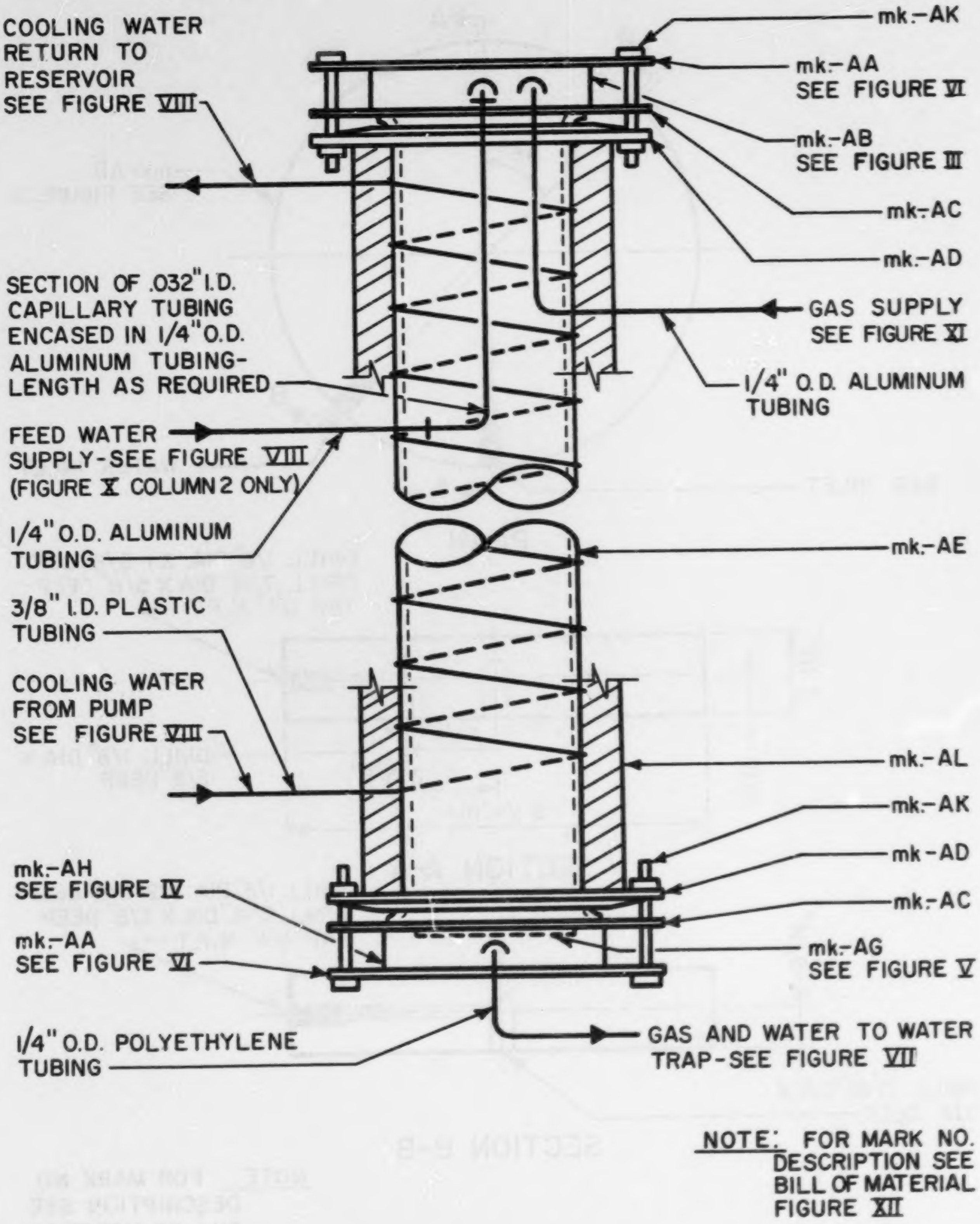

DEMINERALIZED WATER SUPPLY
FLOAT VALVE
STEAM
ELECTRIC HEATER DEAERATOR
WARM WATER
HOT WATER
DRAIN
HEAT EXCHANGERS
ELEVATION OF WATER SUPPLY TO BE 5'-0" ABOVE COLUMN INLET TO ACHIEVE GRAVITY FLOW
FEED WATER
SAMPLE LINE
TO OTHER COLUMNS
CONDUCTIVITY SENSOR
UNI-BED POLISHER
COOLING WATER RETURN
FROM OTHER COLUMNS
PYRITE COLUMN
TO OTHER COLUMNS
GAS & WATER
COOLING WATER SUPPLY
COOLING CONTROL UNIT
COOLING RESERVOIR
COOLING WATER PUMP
SECTION OF .032" I.D. CAPILLARY TUBING ENCASED IN 1/4" O.D. ALUMINUM TUBING LENGTH AS REQUIRED
VENT
BUBBLE TUBE
SAMPLE SEPTUM
FLOWMETER
FILTER
REGULATOR
GAS
GAS SUPPLY
TO OTHER COLUMNS
COMPRESSED GAS CYLINDERS
WATER TRAP
VENT
WATER
WASTE
INSULATION BLOCK
WATER TRAP & SEPARATOR
SAMPLE FLASK

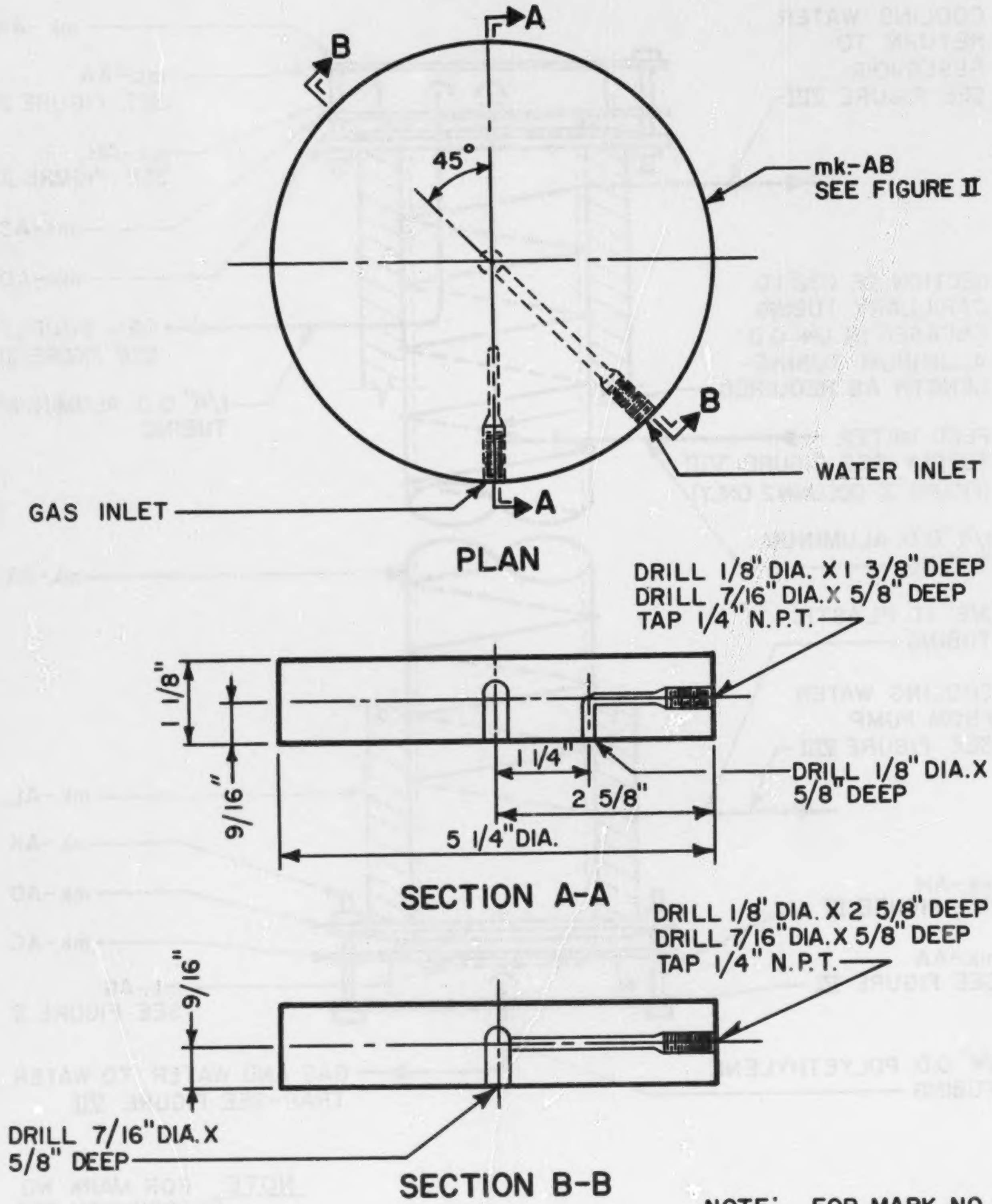
FLOW DIAGRAM - PYRITE COLUMN STUDY-9 COLUMN SYSTEM

FIGURE 1


COOLING WATER RETURN TO RESERVOIR SEE FIGURE VIII
SECTION OF .032" I.D. CAPILLARY TUBING ENCASED IN 1/4" O.D. ALUMINUM TUBING-LENGTH AS REQUIRED
FEED WATER SUPPLY-SEE FIGURE VIII (FIGURE X COLUMN 2 ONLY)
1/4" O.D. ALUMINUM TUBING
3/8" I.D. PLASTIC TUBING
COOLING WATER FROM PUMP SEE FIGURE VIII
mk.-AH SEE FIGURE IV
mk.-AA SEE FIGURE VI
1/4" O.D. POLYETHYLENE TUBING
mk.-AK
mk.-AA SEE FIGURE VI
mk.-AB SEE FIGURE III
mk.-AC
mk.-AD
GAS SUPPLY SEE FIGURE XI
1/4" O.D. ALUMINUM TUBING
mk.-AE
mk.-AL
mk.-AK
mk-AD
mk.-AC
mk.-AG SEE FIGURE V
GAS AND WATER TO WATER TRAP-SEE FIGURE VII
NOTE: FOR MARK NO. DESCRIPTION SEE BILL OF MATERIAL FIGURE XII

COLUMN ASSEMBLY-(TYPICAL 9 COLUMNS)

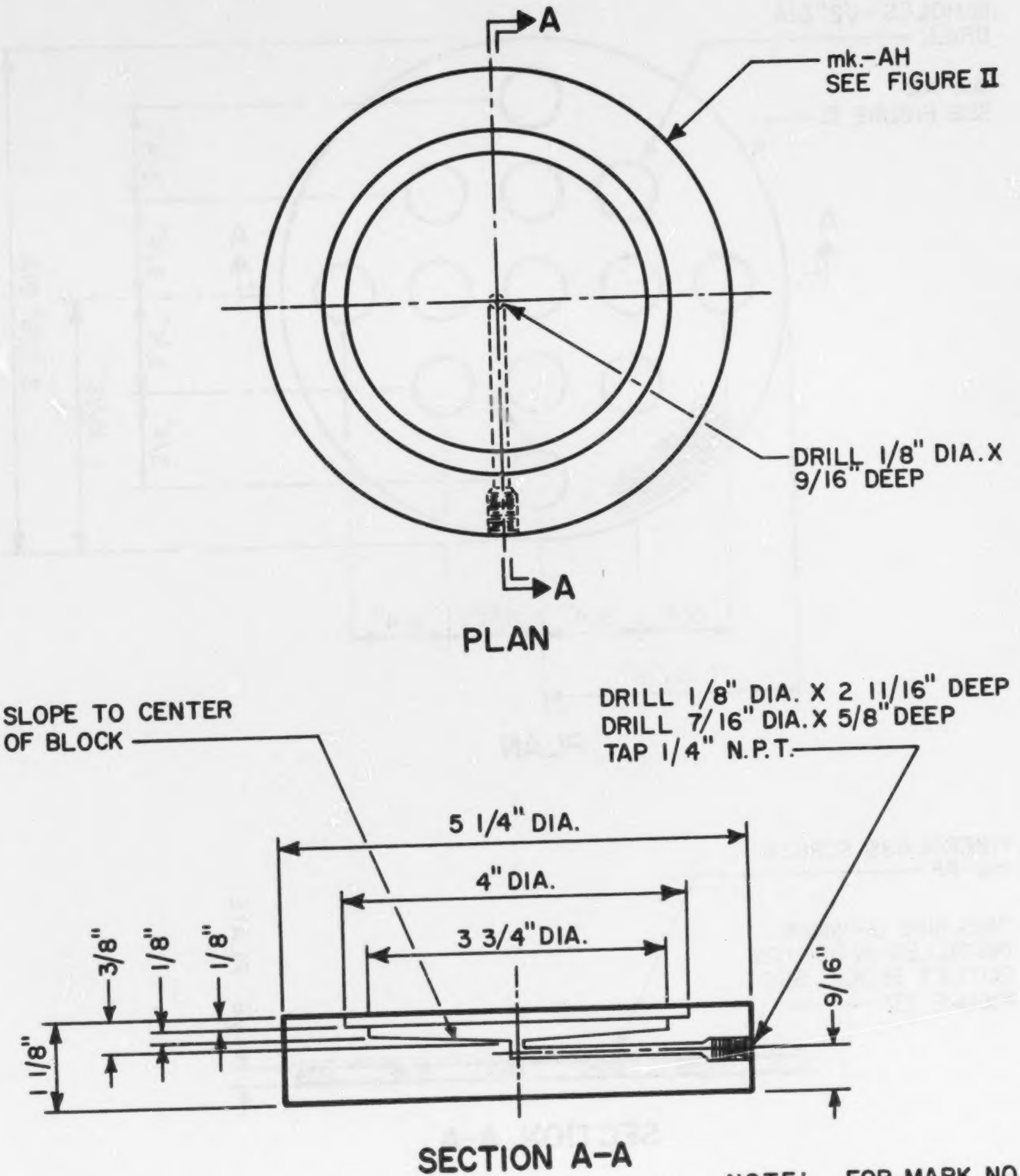
FIGURE II


A
B
45°
mk:-AB
SEE FIGURE II
B
WATER INLET
GAS INLET
A
PLAN
DRILL 1/8" DIA. X 1 3/8" DEEP
DRILL 7/16" DIA. X 5/8" DEEP
TAP 1/4" N.P.T.
1 1/8"
9/16"
1 1/4"
2 5/8"
DRILL 1/8" DIA. X
5/8" DEEP
5 1/4" DIA.
SECTION A-A
DRILL 1/8" DIA. X 2 5/8" DEEP
DRILL 7/16" DIA. X 5/8" DEEP
TAP 1/4" N.P.T.
9/16"
DRILL 7/16" DIA. X
5/8" DEEP
SECTION B-B

NOTE: FOR MARK NO.
DESCRIPTION SEE
BILL OF MATERIAL
FIGURE XII

TOP INLET BLOCK

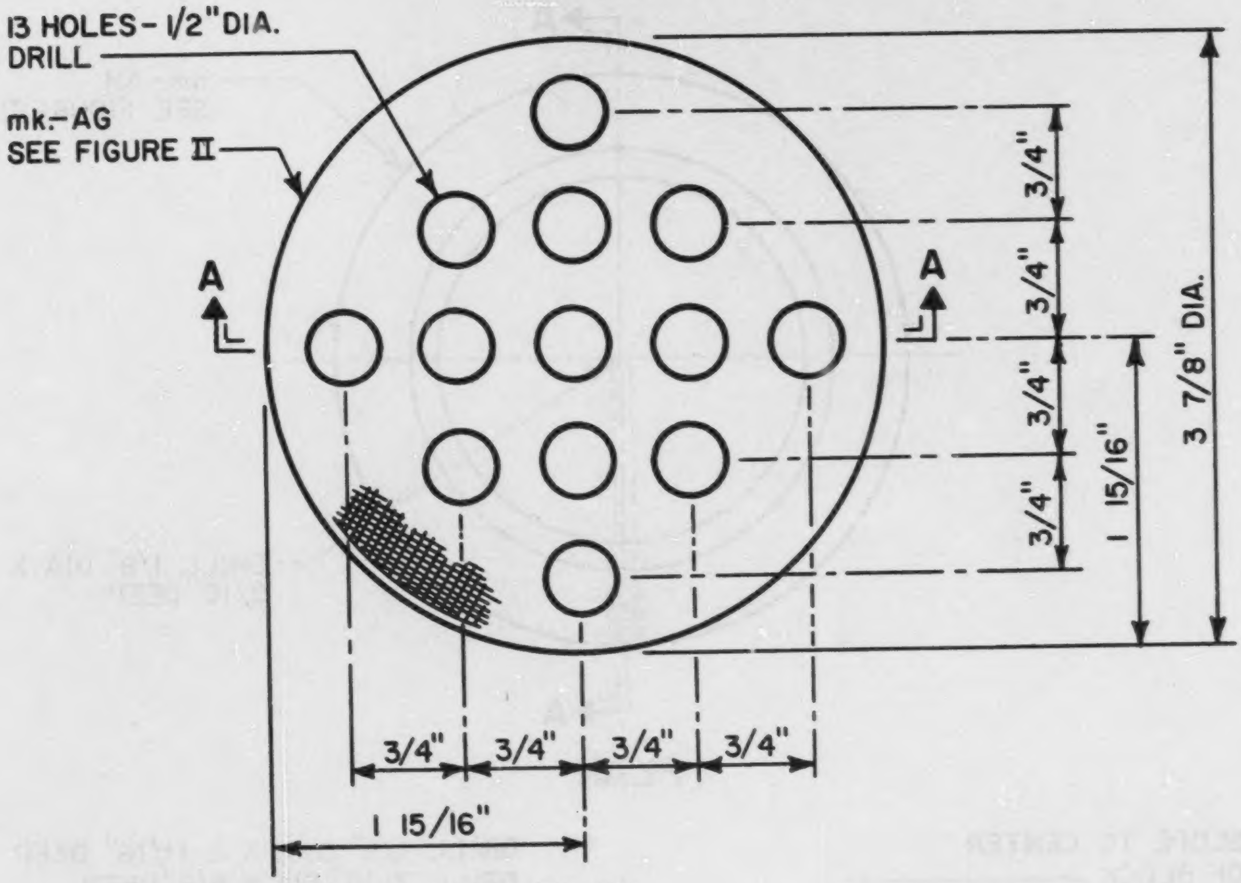
FIGURE III


A
mk.-AH
SEE FIGURE II
DRILL 1/8" DIA. X
9/16" DEEP
A
PLAN
SLOPE TO CENTER
OF BLOCK
DRILL 1/8" DIA. X 2 11/16" DEEP
DRILL 7/16" DIA. X 5/8" DEEP
TAP 1/4" N.P.T.
5 1/4" DIA.
4" DIA.
3 3/4" DIA.
3/8"
1/8"
1/8"
1 1/8"
9/16"
SECTION A-A

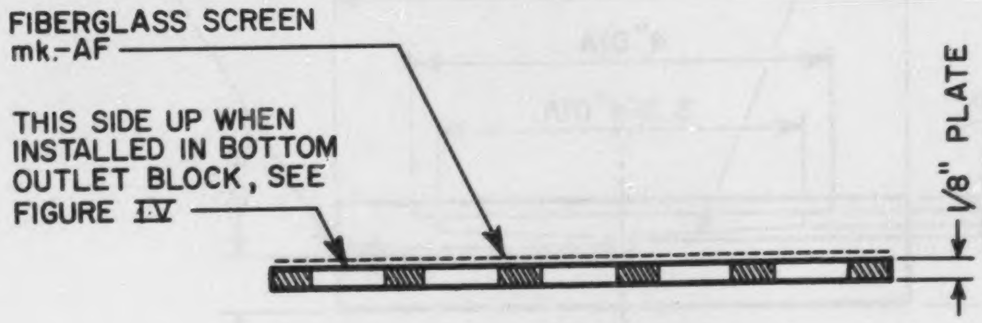
NOTE: FOR MARK NO. DESCRIPTION SEE BILL OF MATERIAL FIGURE XII

BOTTOM OUTLET BLOCK

FIGURE IV


13 HOLES - 1/2" DIA.
DRILL
mk.-AG
SEE FIGURE II
A
A
3/4"
3/4"
3/4"
3/4"
1 15/16"
3 7/8" DIA.
3/4"
3/4"
3/4"
3/4"
1 15/16"

PLAN

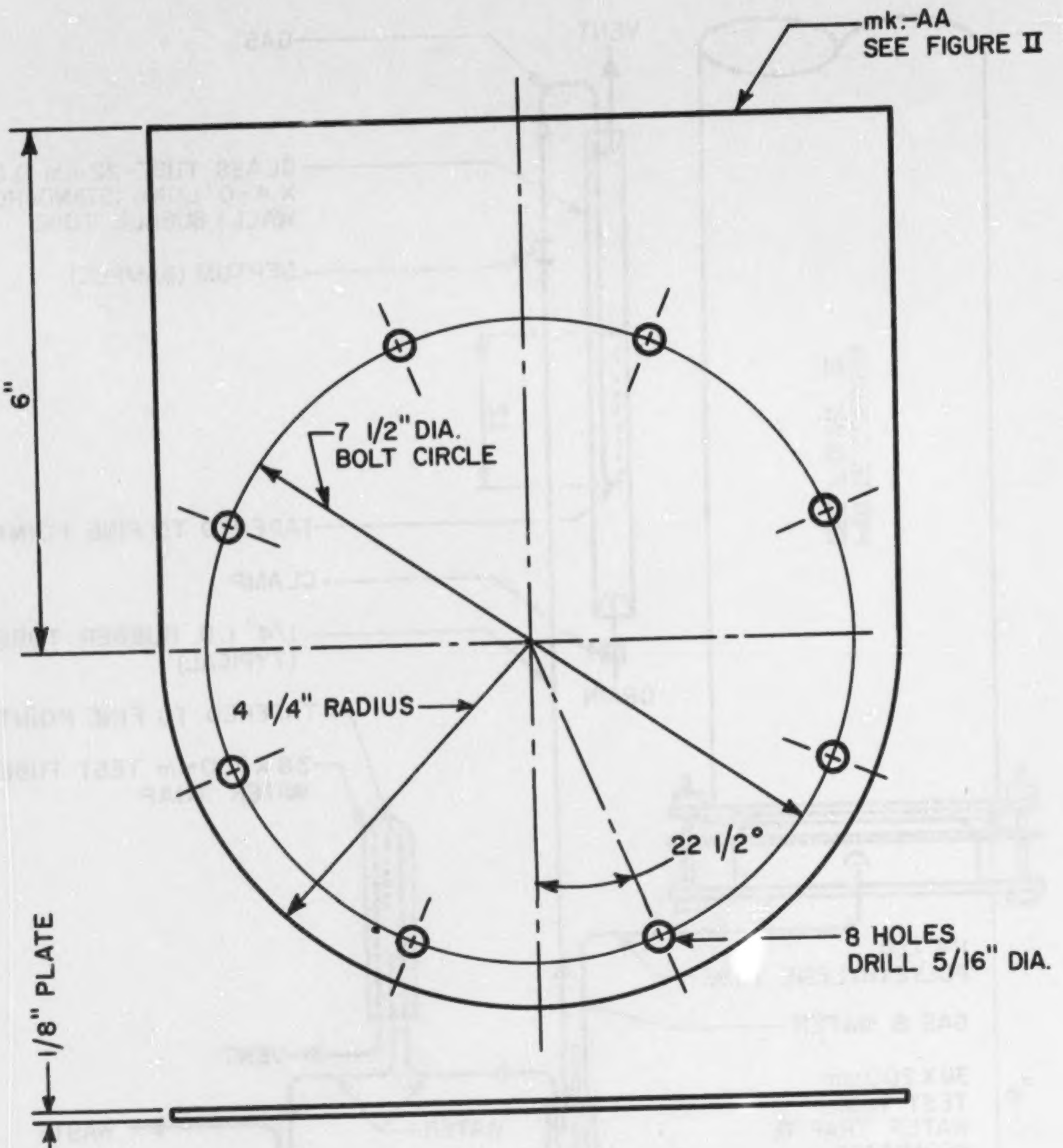

FIBERGLASS SCREEN
mk.-AF
THIS SIDE UP WHEN INSTALLED IN BOTTOM OUTLET BLOCK, SEE FIGURE IV
1/8" PLATE

SECTION A-A

NOTE: FOR MARK NO. DESCRIPTION SEE BILL OF MATERIAL FIGURE XII

RETAINING PLATE ASSEMBLY

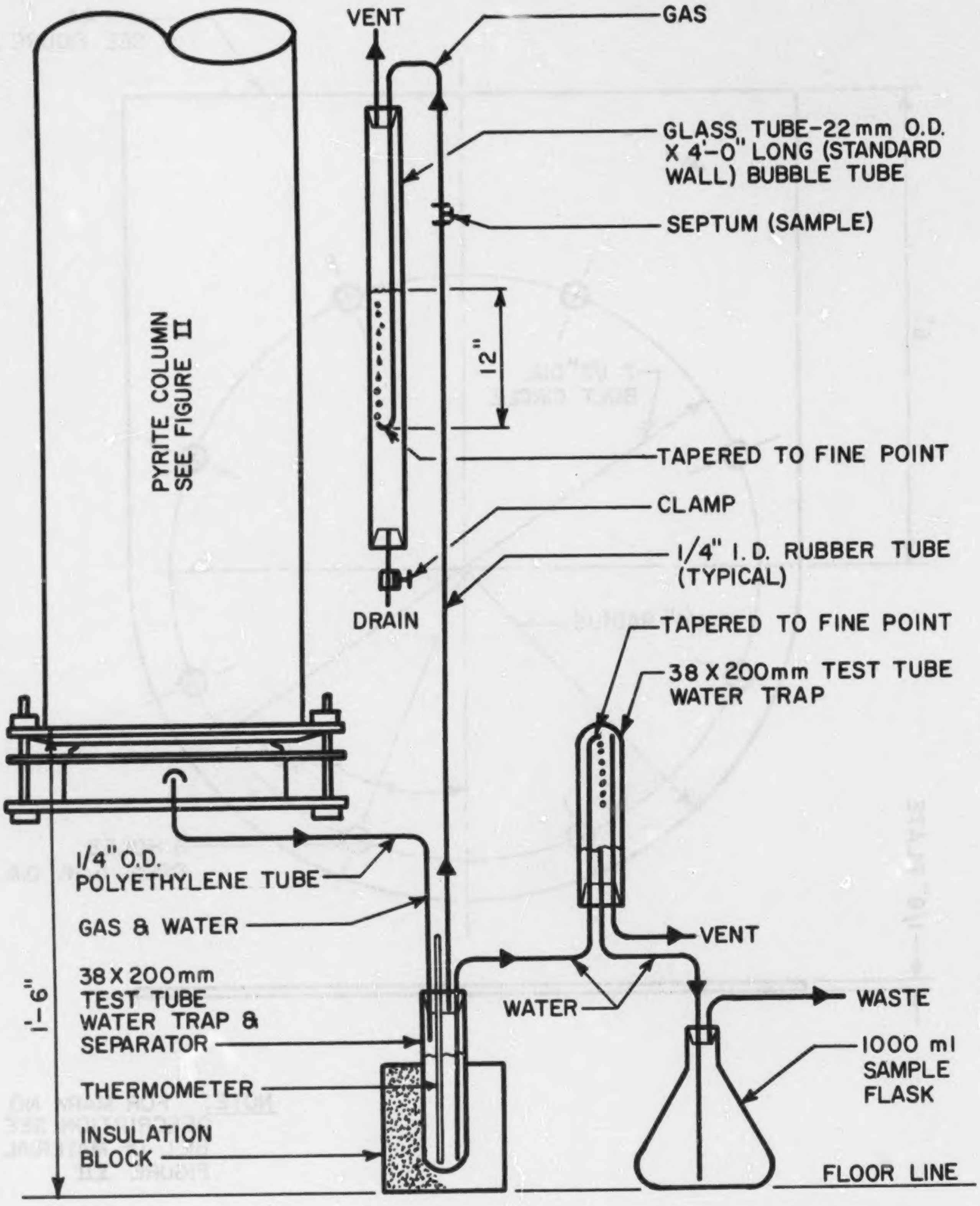
FIGURE V


mk.-AA
SEE FIGURE II
6"
7 1/2" DIA.
BOLT CIRCLE
4 1/4" RADIUS
22 1/2°
8 HOLES
DRILL 5/16" DIA.
1/8" PLATE

NOTE: FOR MARK NO. DESCRIPTION SEE BILL OF MATERIAL FIGURE XII

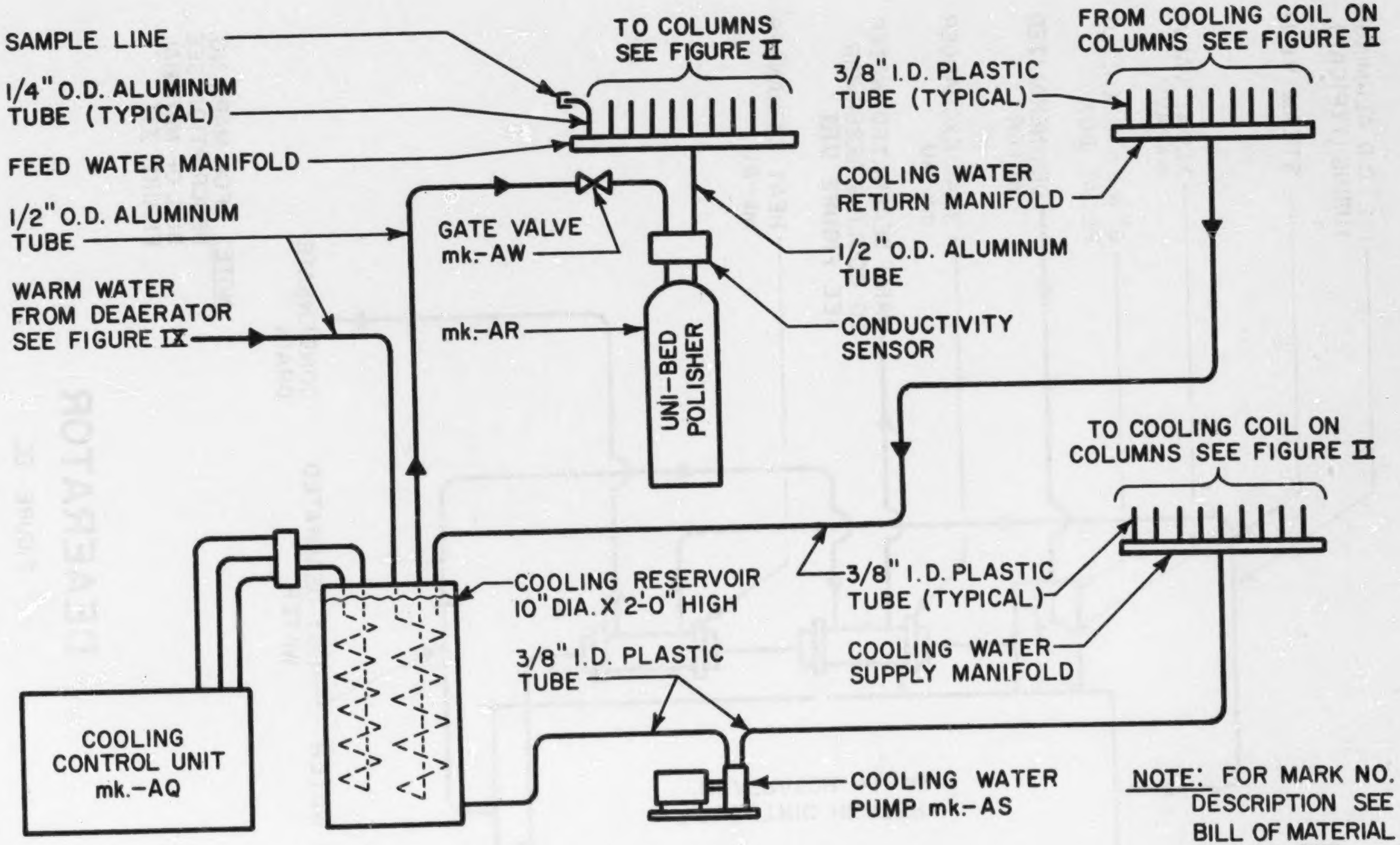
COLUMN SUPPORT PLATE

FIGURE VI


VENT
GAS
GLASS TUBE-22 mm O.D. X 4'-0" LONG (STANDARD WALL) BUBBLE TUBE
SEPTUM (SAMPLE)
12"
PYRITE COLUMN SEE FIGURE II
TAPERED TO FINE POINT
CLAMP
1/4" I. D. RUBBER TUBE (TYPICAL)
DRAIN
TAPERED TO FINE POINT
38 X 200mm TEST TUBE WATER TRAP
1/4" O.D. POLYETHYLENE TUBE
GAS & WATER
VENT
38 X 200mm TEST TUBE WATER TRAP & SEPARATOR
WATER
WASTE
1000 ml SAMPLE FLASK
THERMOMETER
INSULATION BLOCK
1'-6"
FLOOR LINE

WASTE WATER & WASTE GAS DISPOSAL SYS.

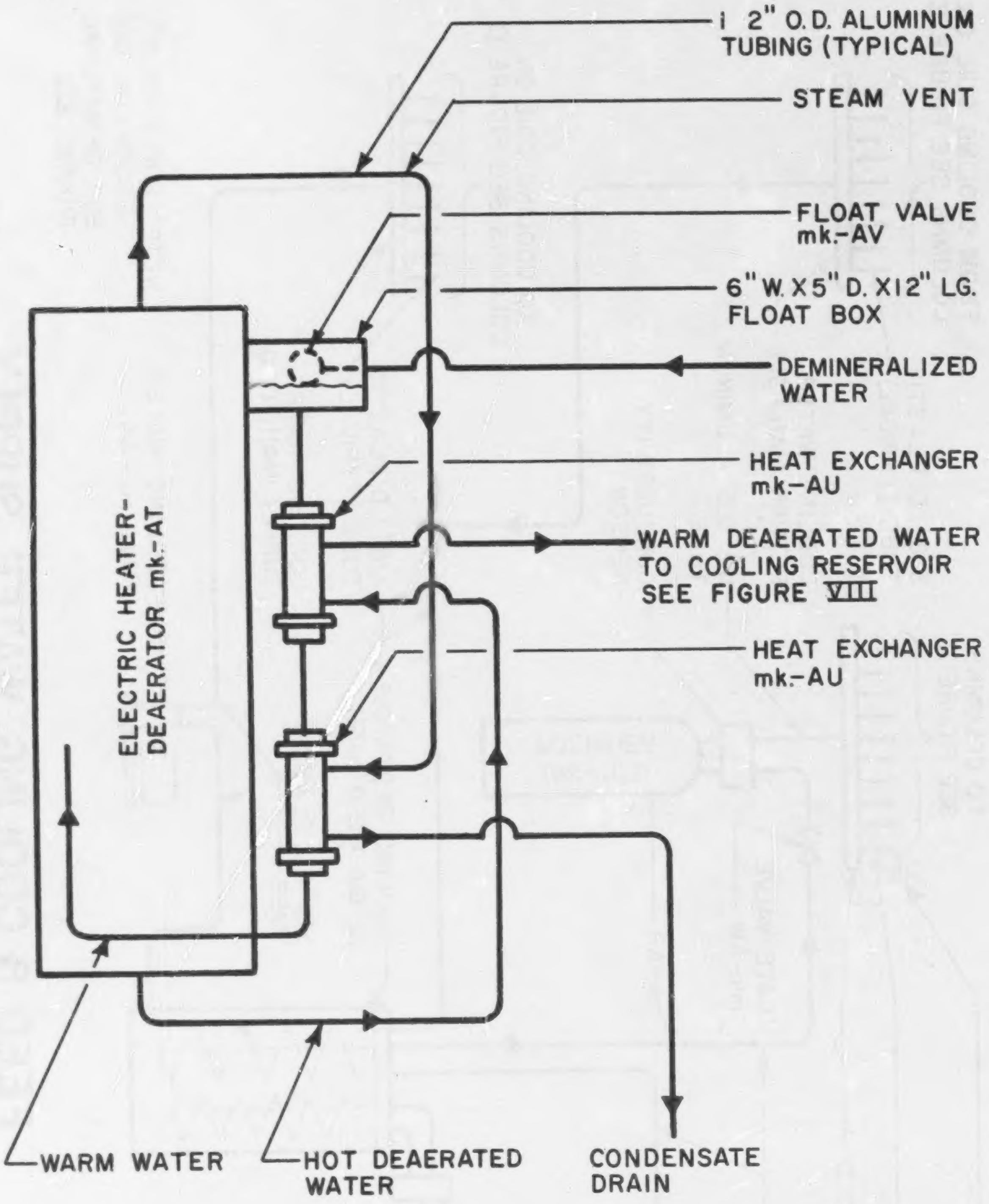
FIGURE VII


SAMPLE LINE
1/4" O.D. ALUMINUM TUBE (TYPICAL)
FEED WATER MANIFOLD
1/2" O.D. ALUMINUM TUBE
WARM WATER FROM DEAERATOR SEE FIGURE IX
TO COLUMNS SEE FIGURE II
GATE VALVE mk.-AW
mk.-AR
UNI-BED POLISHER
1/2" O.D. ALUMINUM TUBE
CONDUCTIVITY SENSOR
3/8" I.D. PLASTIC TUBE (TYPICAL)
FROM COOLING COIL ON COLUMNS SEE FIGURE II
COOLING WATER RETURN MANIFOLD
TO COOLING COIL ON COLUMNS SEE FIGURE II
3/8" I.D. PLASTIC TUBE (TYPICAL)
COOLING WATER SUPPLY MANIFOLD
COOLING RESERVOIR 10" DIA. X 2'-0" HIGH
3/8" I.D. PLASTIC TUBE
COOLING CONTROL UNIT mk.-AQ
COOLING WATER PUMP mk.-AS

NOTE: FOR MARK NO. DESCRIPTION SEE BILL OF MATERIAL FIGURE XII

FEED & COOLING WATER SUPPLY

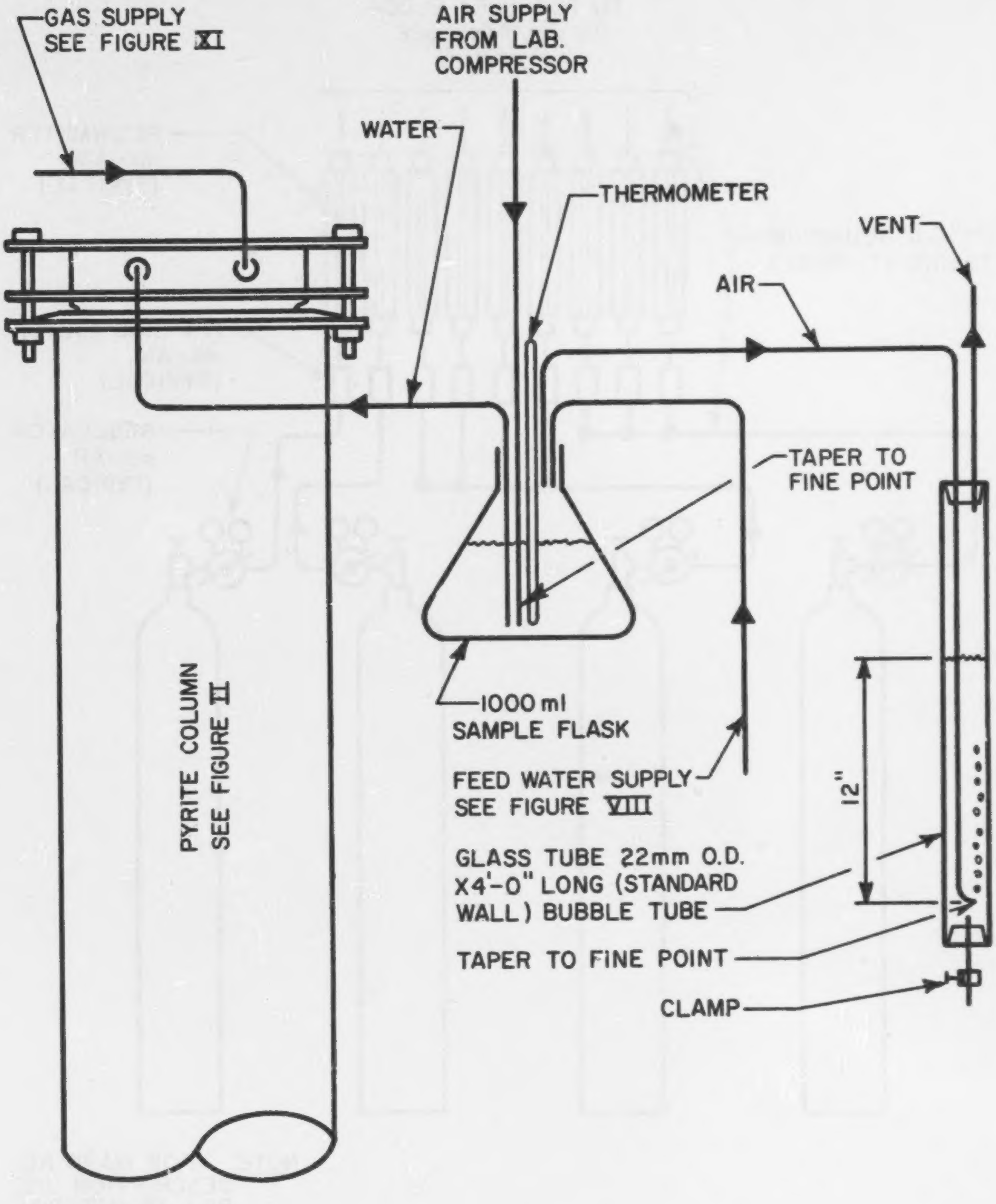
FIGURE VIII


1 2" O.D. ALUMINUM TUBING (TYPICAL)
STEAM VENT
FLOAT VALVE mk.-AV
6" W. X 5" D. X 12" LG. FLOAT BOX
DEMINERALIZED WATER
HEAT EXCHANGER mk.-AU
WARM DEAERATED WATER TO COOLING RESERVOIR SEE FIGURE VIII
HEAT EXCHANGER mk.-AU
ELECTRIC HEATER-DEAERATOR mk.-AT
WARM WATER
HOT DEAERATED WATER
CONDENSATE DRAIN

NOTE: FOR MARK NO. DESCRIPTION SEE BILL OF MATERIAL FIGURE XII

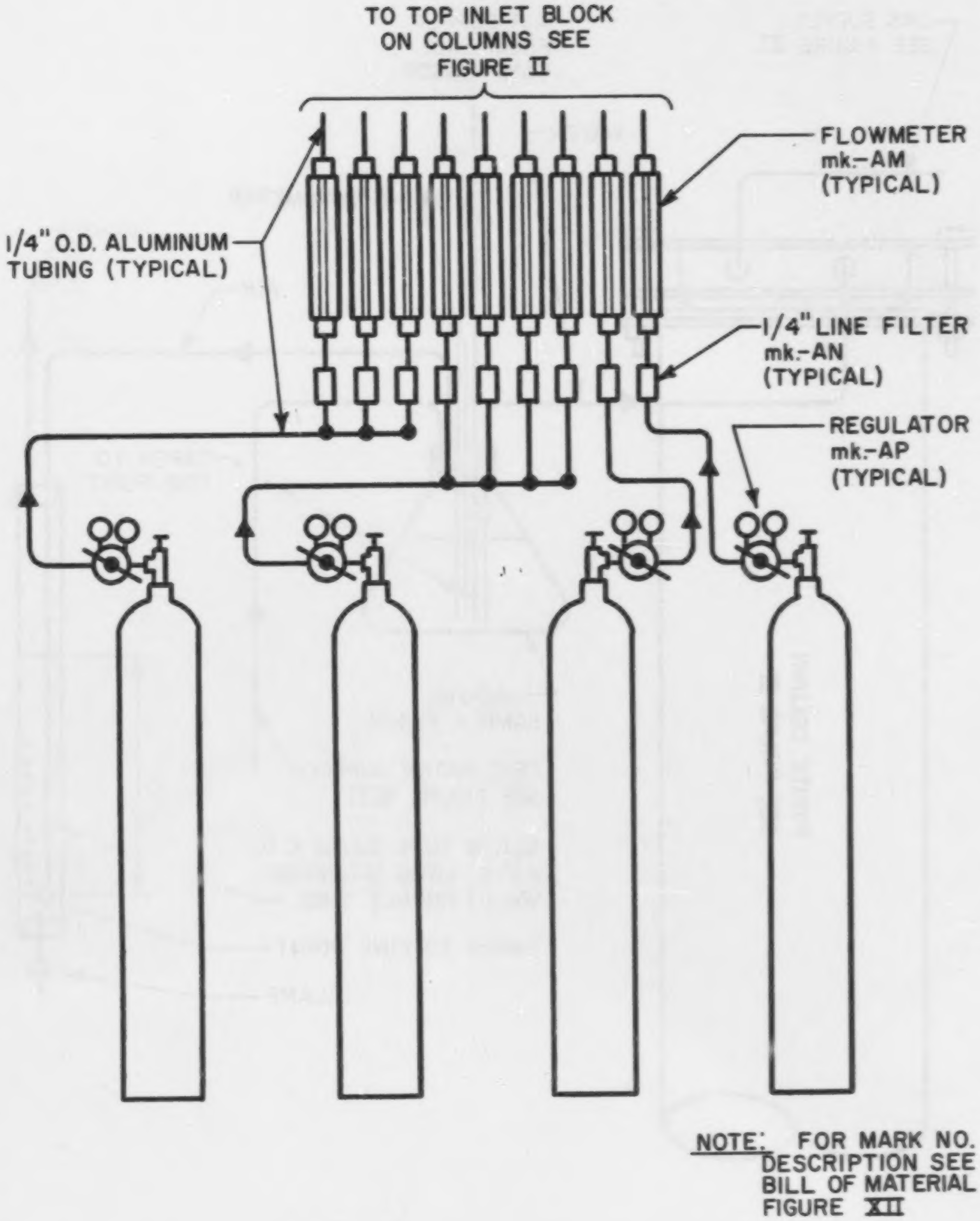
DEAERATOR

FIGURE IX


GAS SUPPLY SEE FIGURE XI
AIR SUPPLY FROM LAB. COMPRESSOR
WATER
THERMOMETER
VENT
AIR
TAPER TO FINE POINT
PYRITE COLUMN SEE FIGURE II
1000 ml SAMPLE FLASK
FEED WATER SUPPLY SEE FIGURE VIII
12"
GLASS TUBE 22mm O.D. X4'-0" LONG (STANDARD WALL) BUBBLE TUBE
TAPER TO FINE POINT
CLAMP

AERATED FEEDWATER SYSTEM (COLUMN NO 2)

FIGURE X


TO TOP INLET BLOCK ON COLUMNS SEE FIGURE II
FLOWMETER mk.-AM (TYPICAL)
1/4" O.D. ALUMINUM TUBING (TYPICAL)
1/4" LINE FILTER mk.-AN (TYPICAL)
REGULATOR mk.-AP (TYPICAL)
NOTE: FOR MARK NO. DESCRIPTION SEE BILL OF MATERIAL FIGURE XII

COMPRESSED GAS SUPPLY

FIGURE XI

Mark No.	No. Req'd	Description	Mat'l	Remarks
AA	18	Plate 1/8" x 8 1/2" x 10 1/4" Long	C. Stl.	See Fig VI
AB	9	1 1/8" Thick x 5 1/4" Diameter	Acrylic Plastic	See Fig III
AC	18	4" Gaskets Kimax No. 7256	Rubber	See Fig II
AD	18	4" Flanges Kimax No. 7151	Alum.	See Fig II
AE	9	4" Glass Pipe x 6'-0" Long Kimax	Glass	See Fig II
AF	9	3 7/8" Diameter Fine Mesh Fiberglass Screen		See Fig V
AG	9	Plate 1/8" x 3 7/8" Diameter	S. Stl.	See Fig V
AH	9	1 1/8" Thick x 5 1/4" Diameter	Acrylic Plastic	See Fig IV
AK	144	1/4" Diameter Bolts w/nuts x 2 1/2" Long	Stl.	See Fig II
AL	9	1" Thick Insulation x 1'-3" x 5'-10" Long Fiberglass Insulation		See Fig II
AM	9	Flowmeter-Matheson No. 610 - Mounting Type No. 620 - Model No. 622PB-1		See Fig XI
AN	9	Line Filter - Matheson No. 410X	Brass	See Fig XI
AP	4	Single State General Purpose Regulator - Matheson Model No. 1L-320		See Fig XI
AQ	1	Constant Flow Portable Cooling Unit Blue M Electric Co. Model No. PCC-24A-2		See Fig VIII
AR	1	Demineralizer Culligan Unibed Model No. E68-9223		See Fig VIII
AS	1	Cooling Water Pump Eastern Centrifugal Model No. D-6		See Fig VIII

BILL OF MATERIAL

FIGURE XII

Mark No.	No. Req'd	Description	Mat'l	Remarks
AT	1	Water Heater - A.O. Smith Mark III Model No. GED-40 40 Gal. Cap. or Equal		See Fig IX
AU	2	Heater Exchangers		See Fig IX
AV	1	MPT Float Valve 1/2" Grainger Stock No. 2x524 with 4 1/2" Diameter Float Stock No. 2x526		See Fig IX
AW	1	Gate Valve - 1/4"		See Fig VIII

BILL OF MATERIAL (Continued)

FIGURE XII

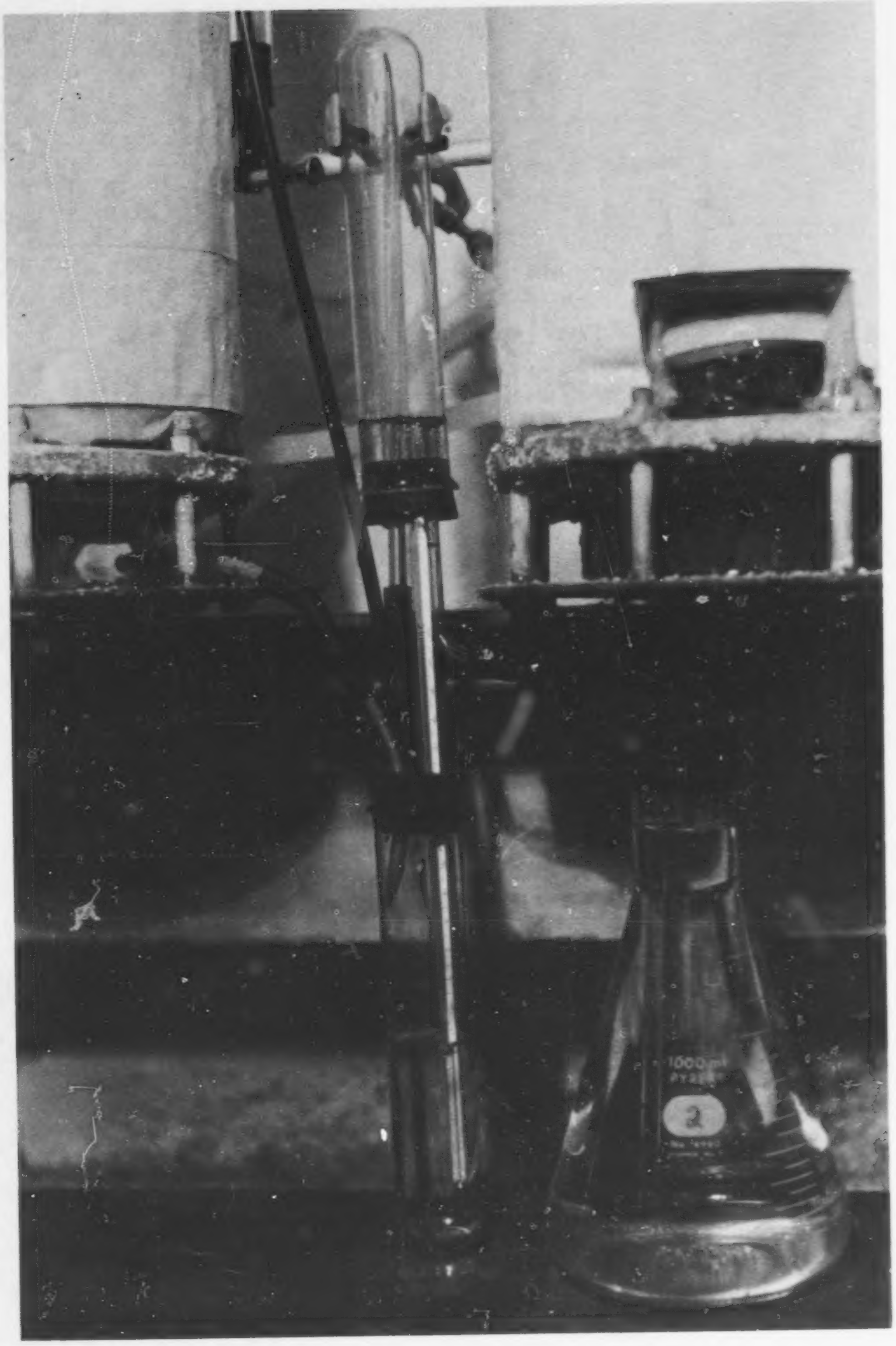


FIGURE XIII

WASTEWATER AND WASTE GAS DISPOSAL SYSTEM

NOT REPRODUCIBLE

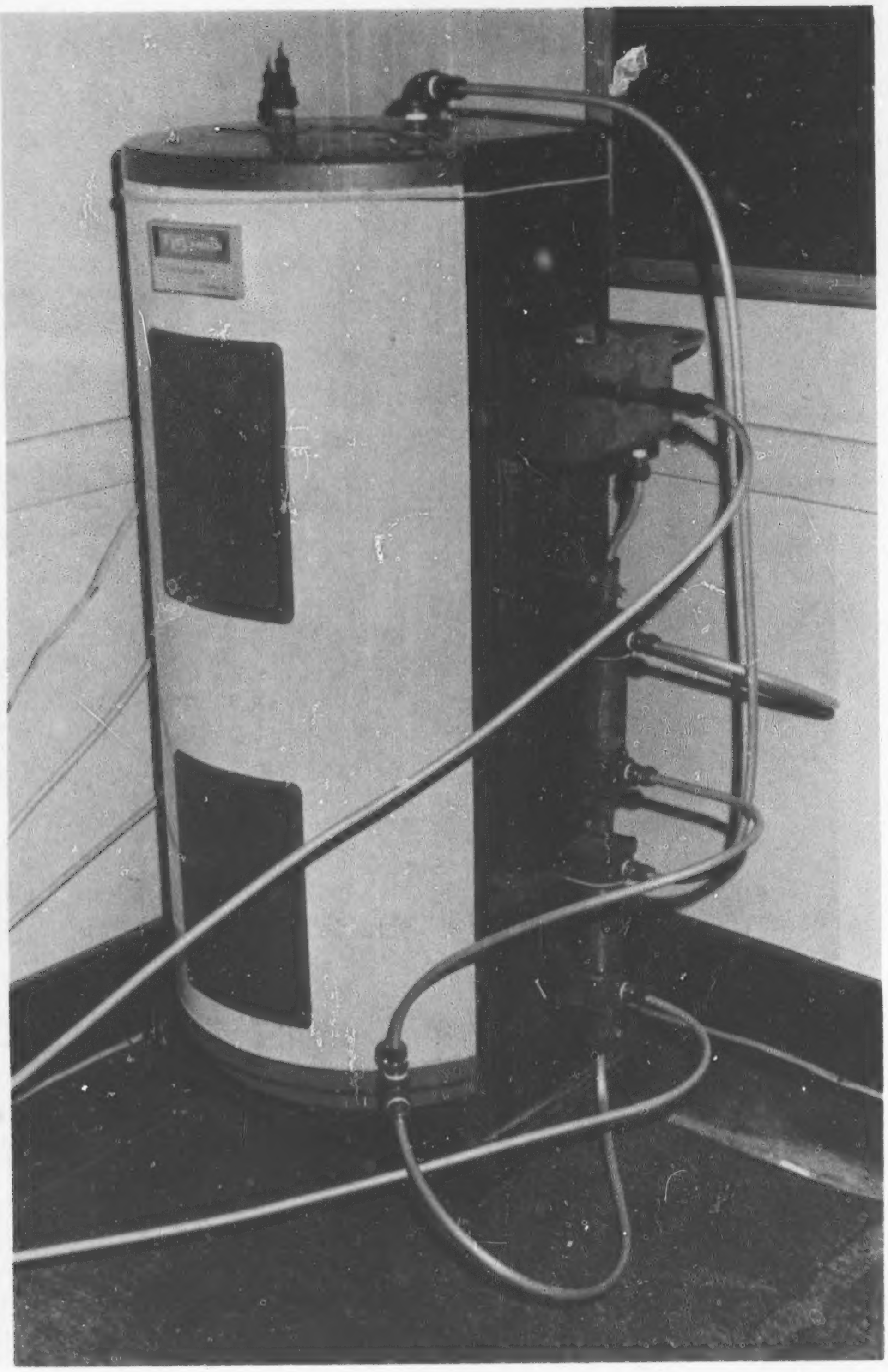


FIGURE XIV

DEAERATOR

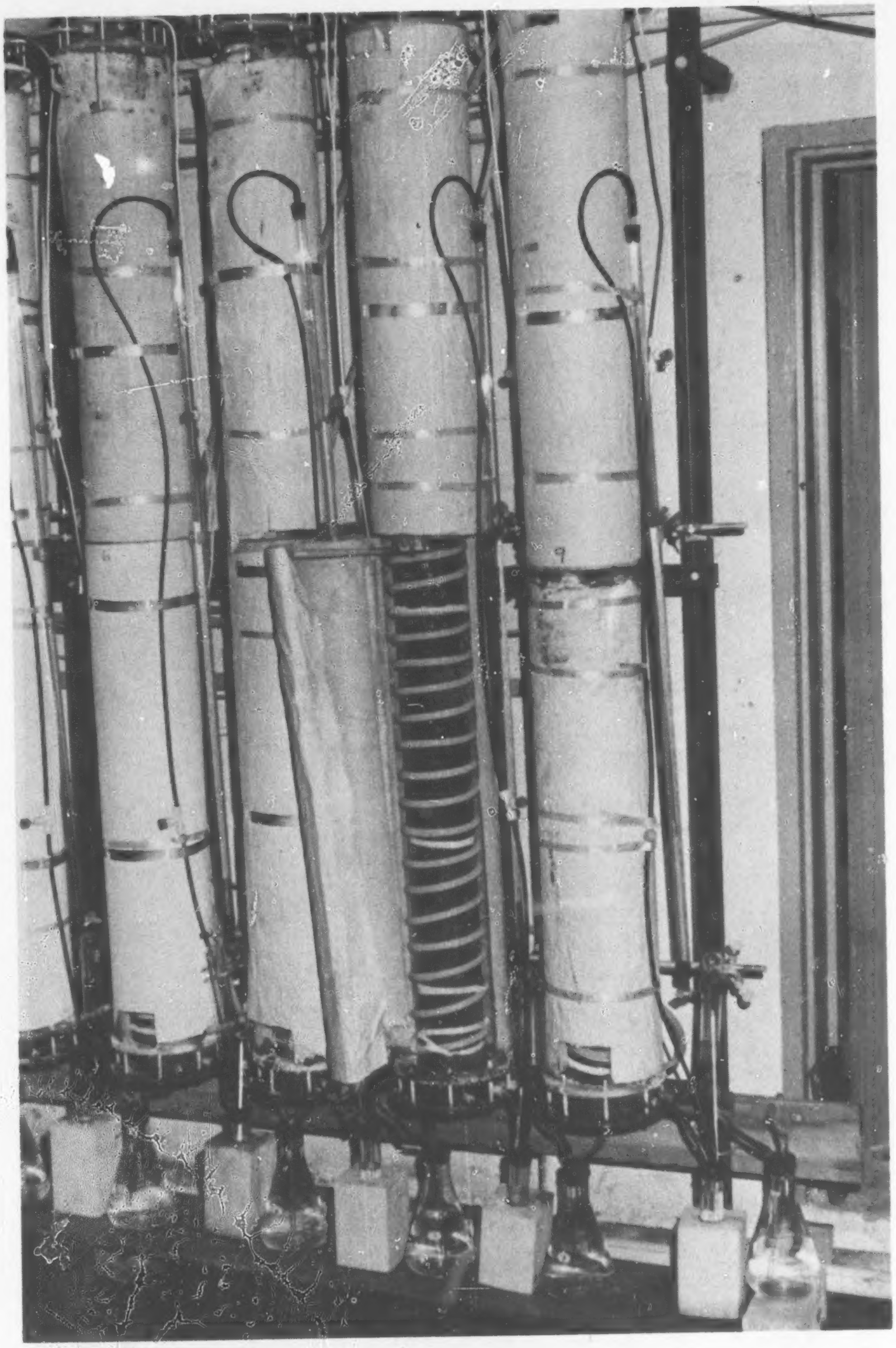


FIGURE XV

COLUMN COOLING ARRANGEMENT

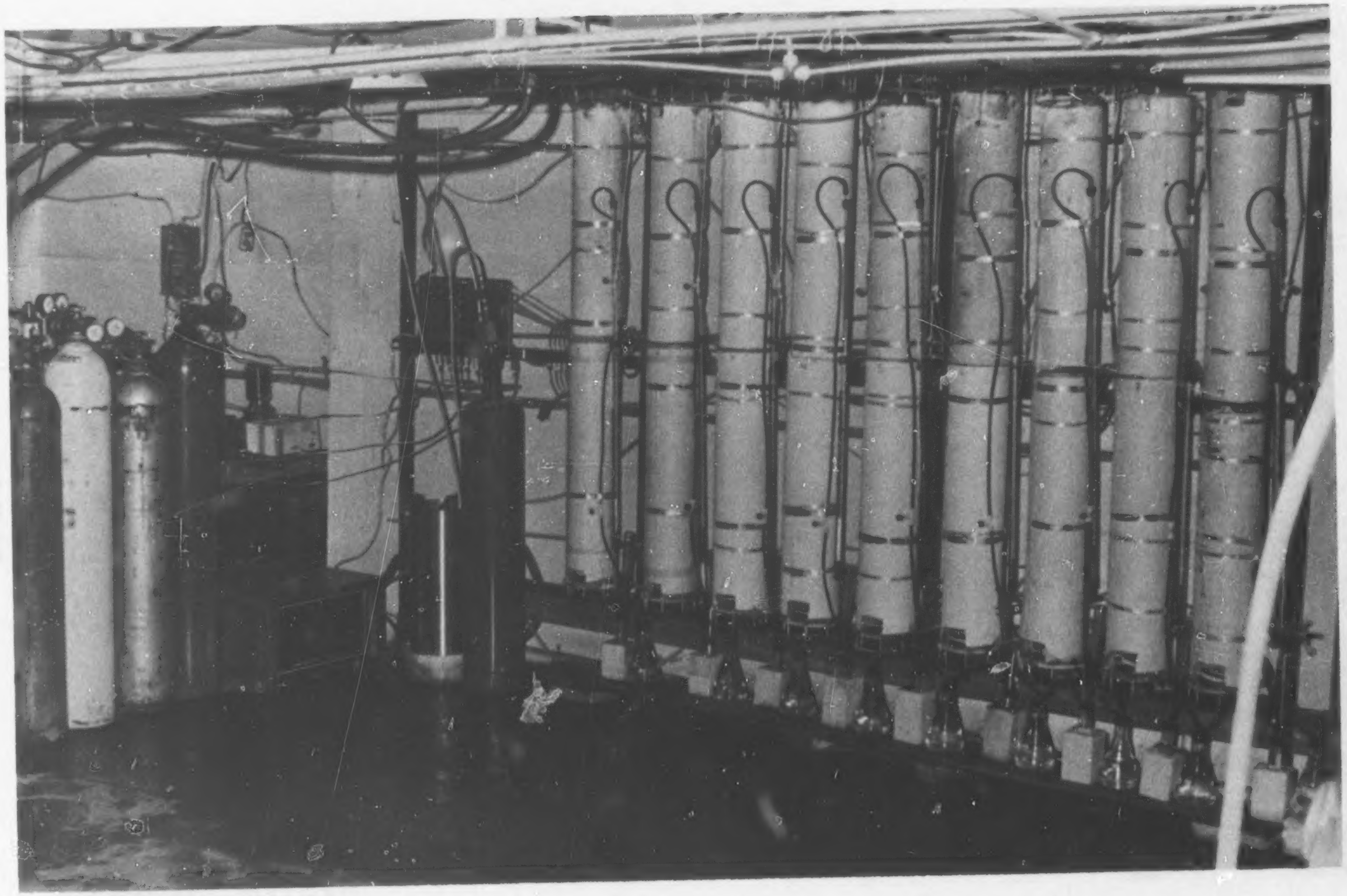


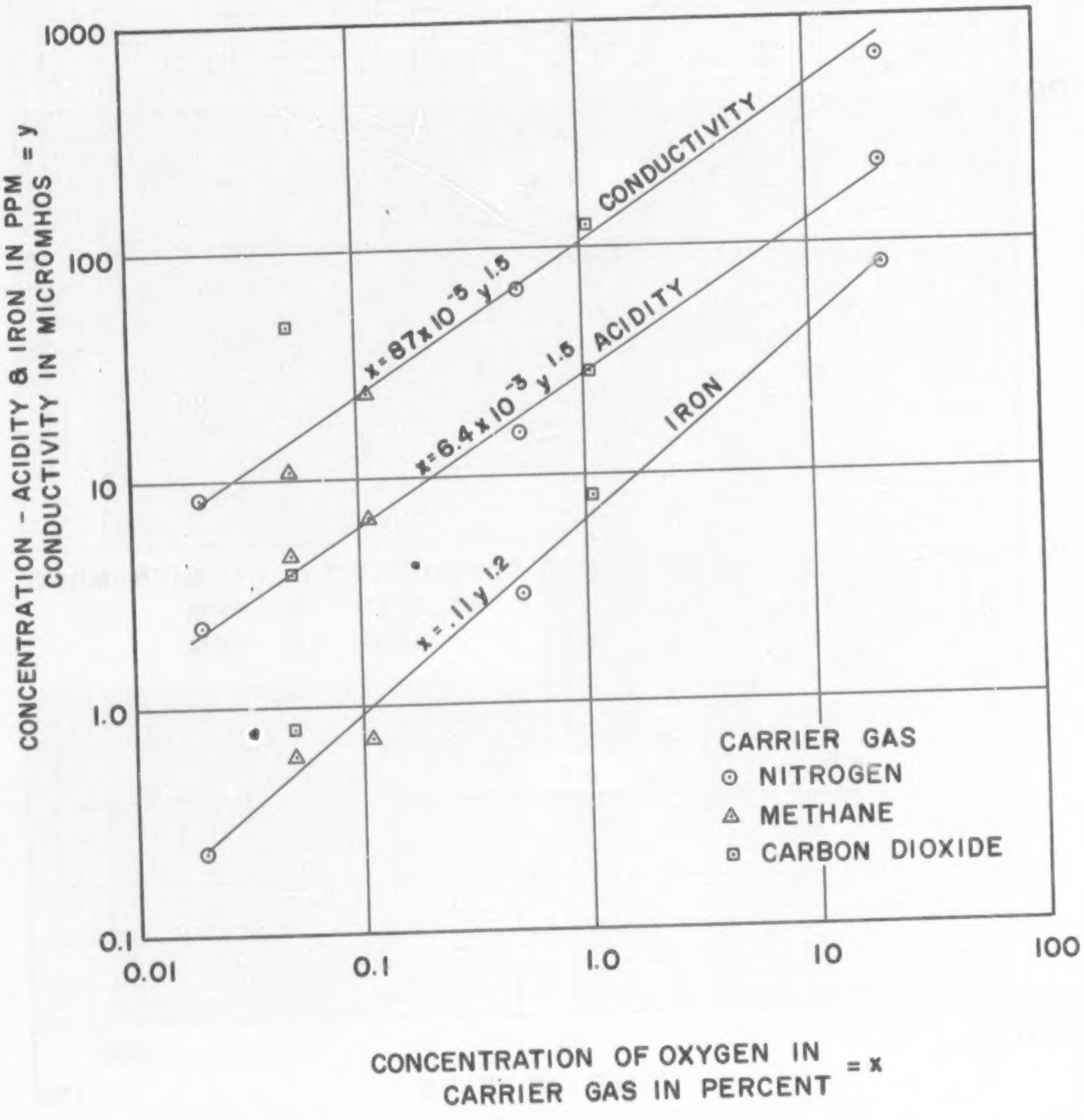
FIGURE XVI

APPARATUS AND GENERAL ARRANGEMENT OF EQUIPMENT

NOT REPRODUCIBLE

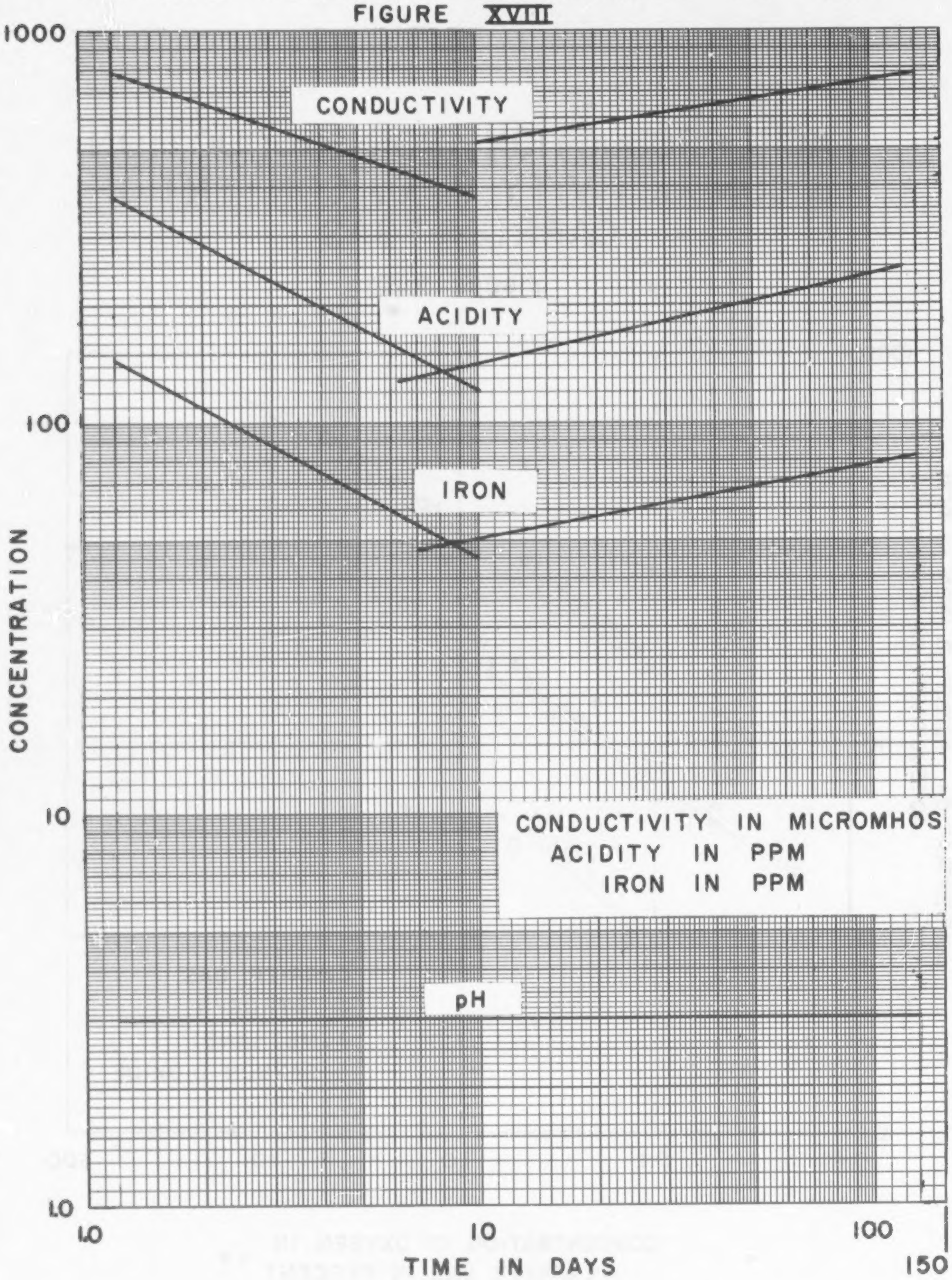
ACID PRODUCTION, IRON PRODUCTION & CONDUCTIVITY Vs O2 CONTENT OF CARRIER GAS

FIGURE XVII



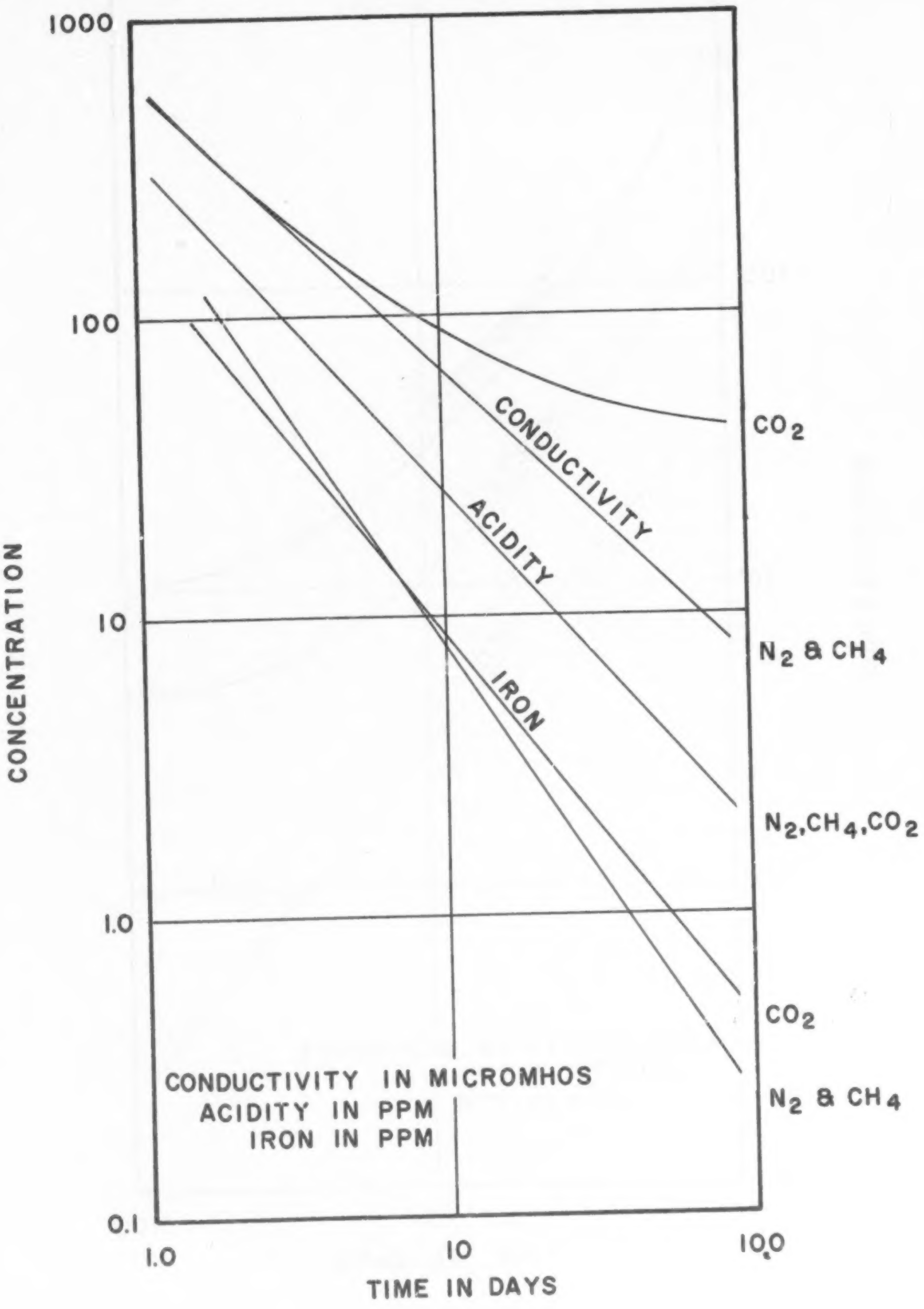
TYPICAL COLUMN PERFORMANCE ON AIR

FIGURE XVIII



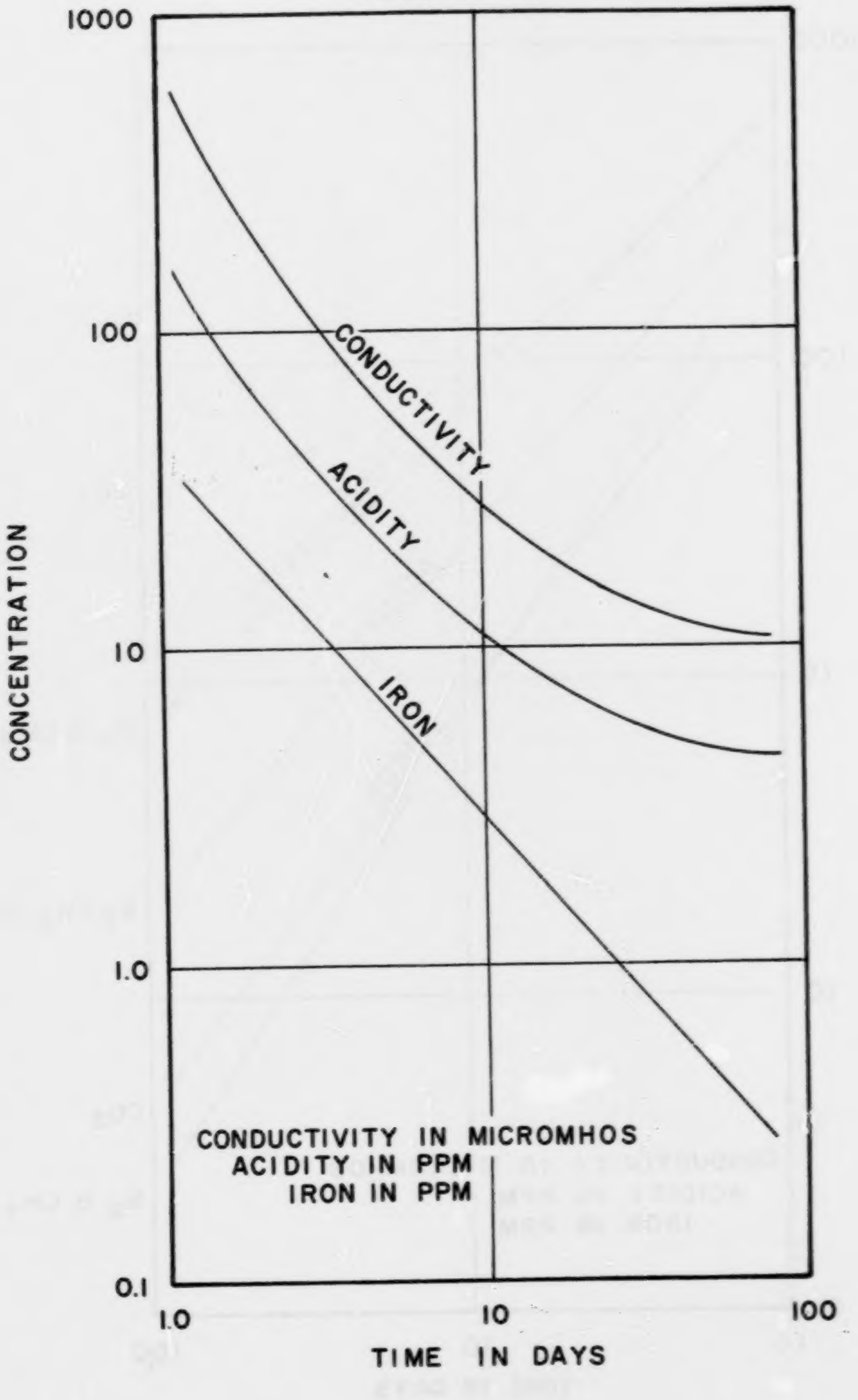
TYPICAL CURVE FOR RATE OF FALLOFF OF ACID & IRON PRODUCTION FOR FRESH PACKED COLUMNS WITH INERT GAS

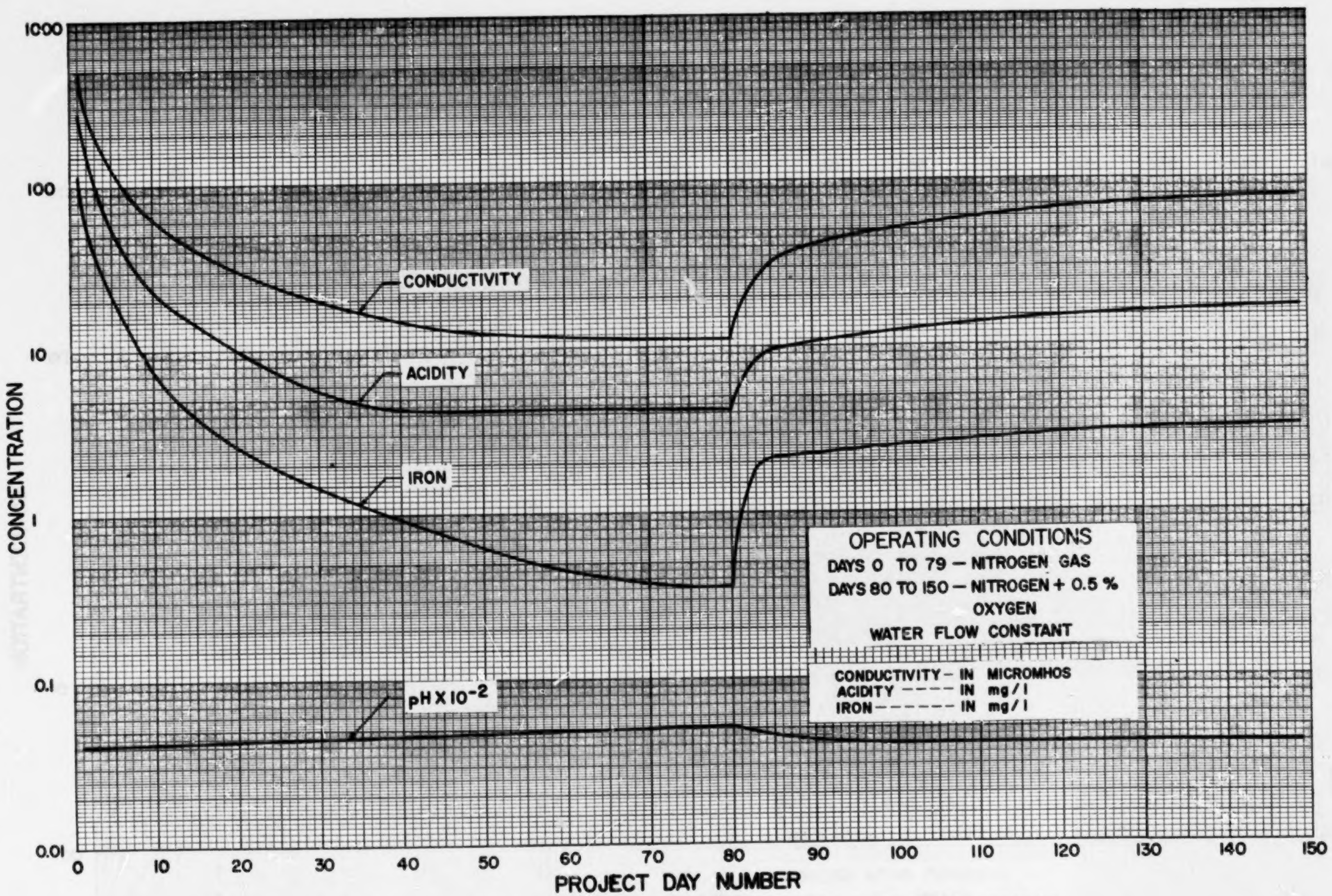
FIGURE XIX



TYPICAL CURVE FOR RATE OF FALLOFF OF ACID & IRON PRODUCTION WHEN BLANKETING GAS WAS SWITCHED FROM AIR TO EITHER N_2 OR CH_4

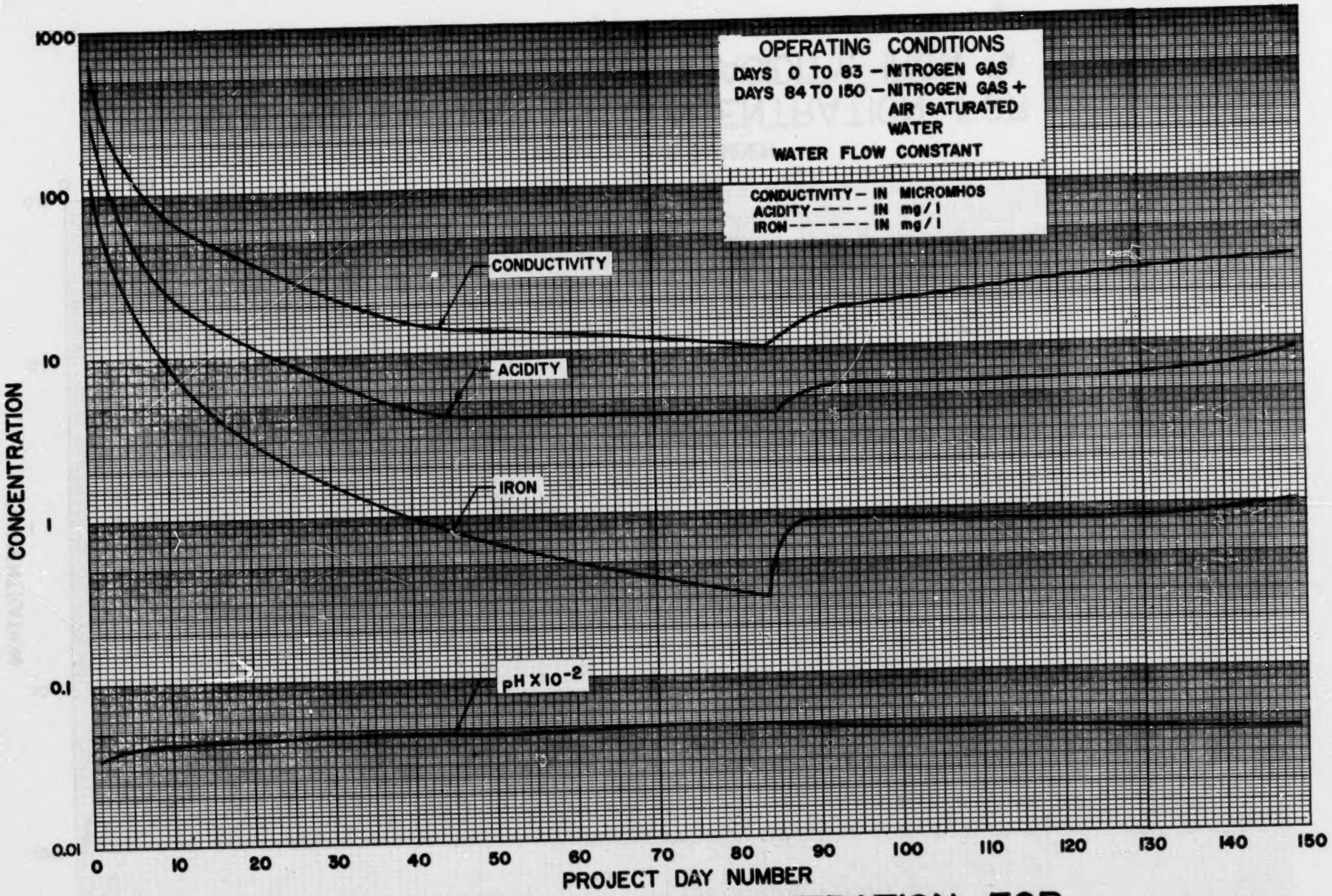
FIGURE XX





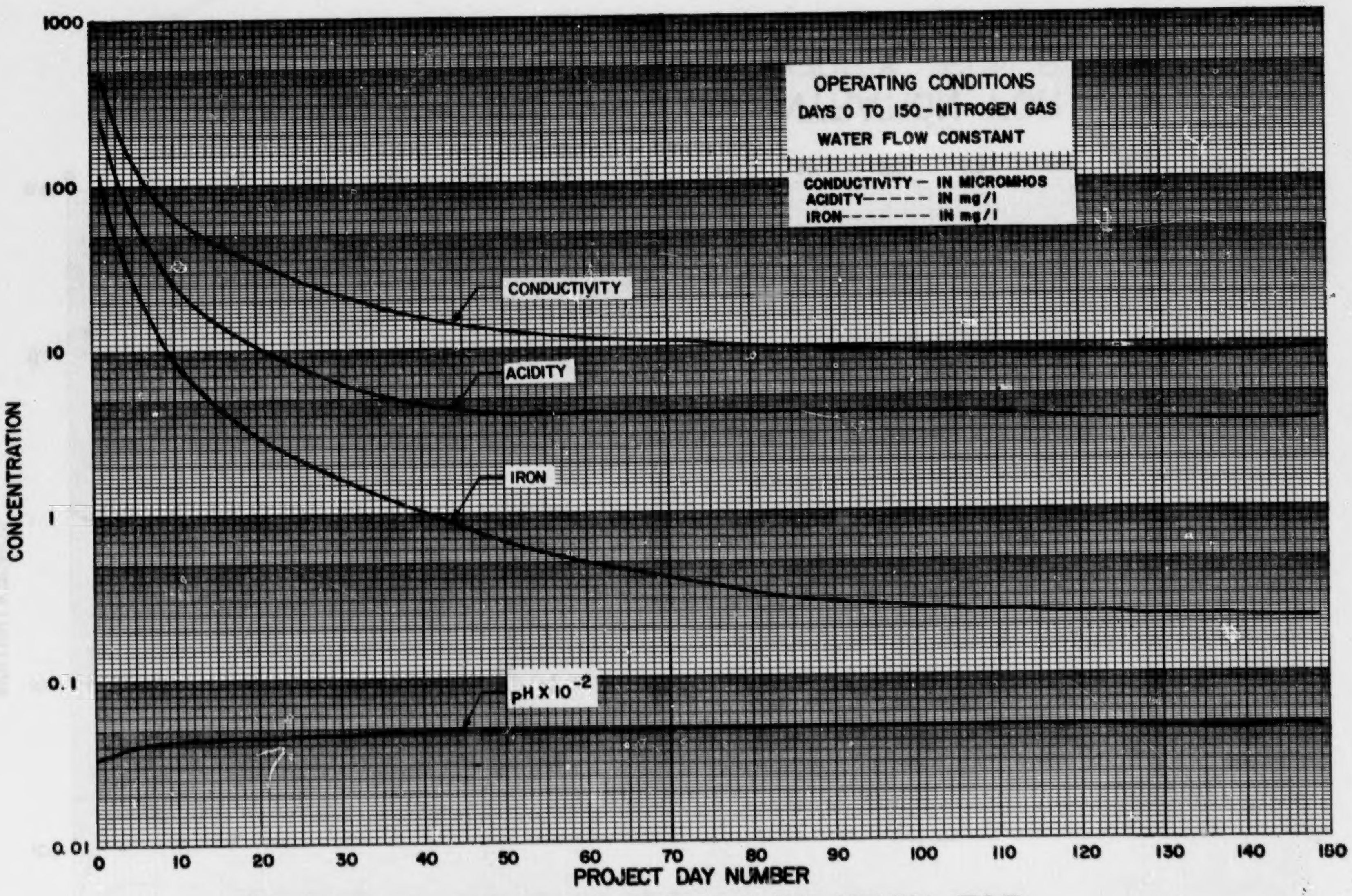
COLUMN 1 - TIME VS CONCENTRATION FOR CONDUCTIVITY, ACIDITY, IRON & pH

FIGURE XXI



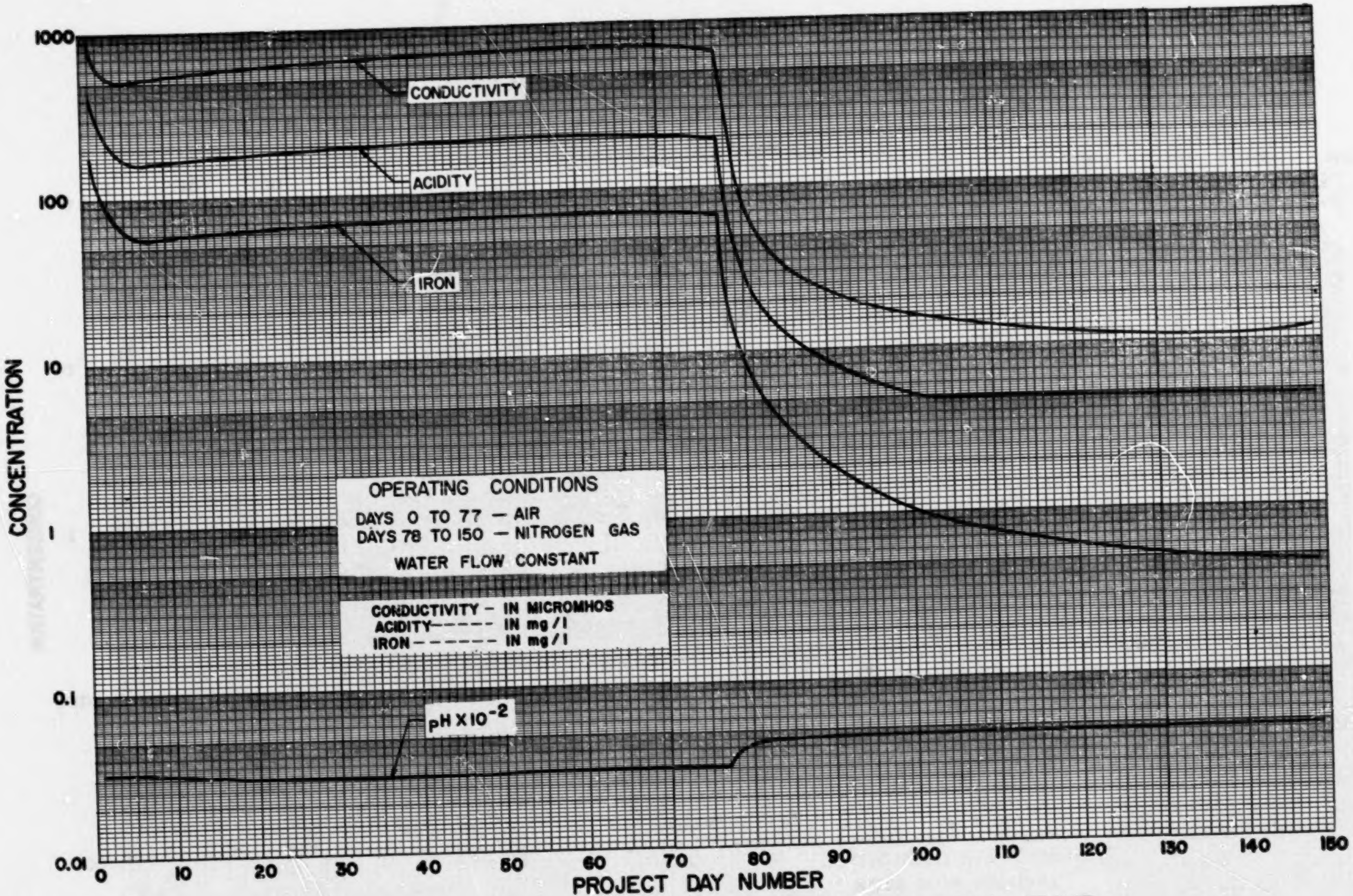
COLUMN 2 – TIME VS CONCENTRATION FOR CONDUCTIVITY, ACIDITY, IRON & pH

FIGURE XXII



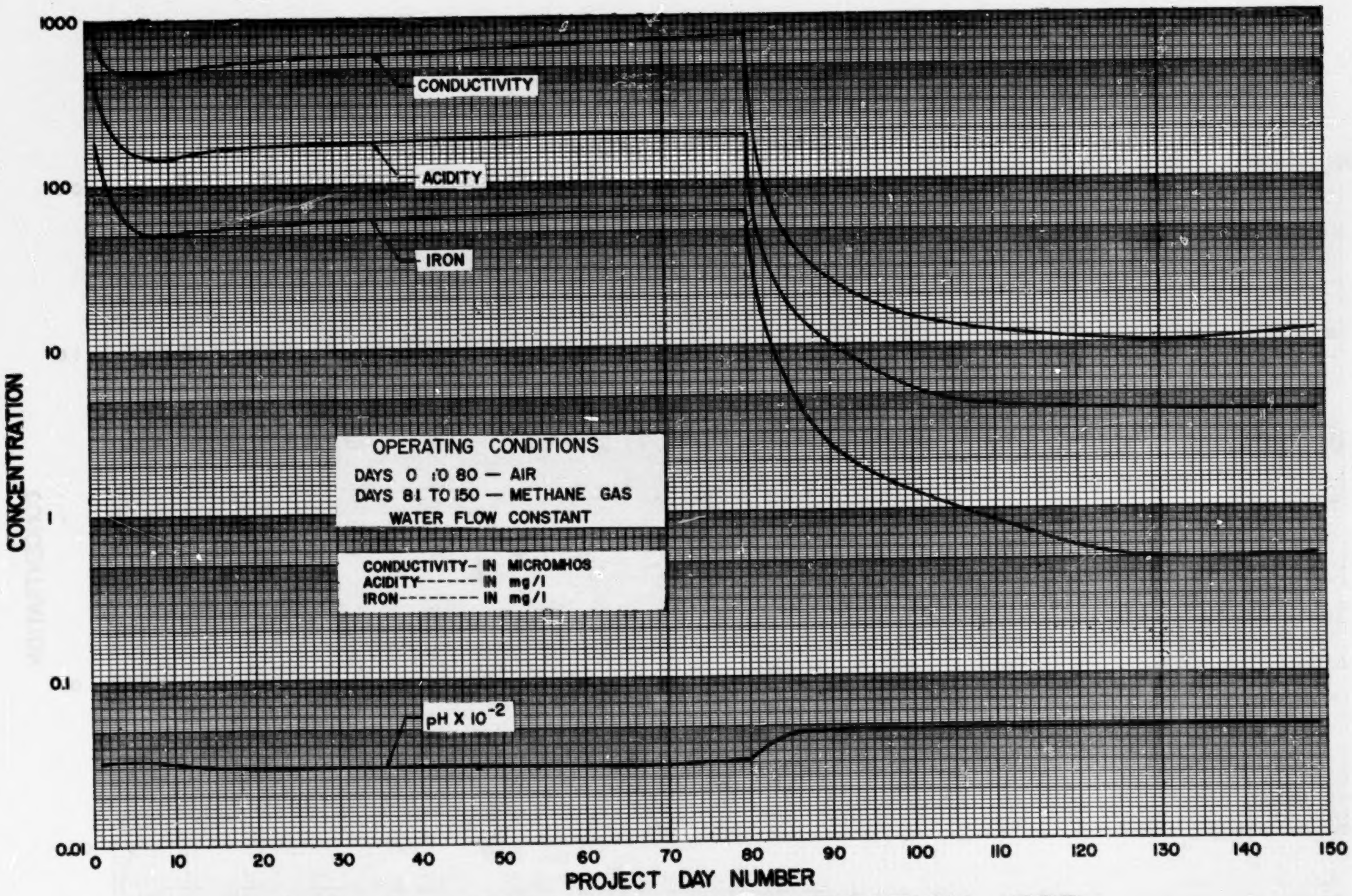
COLUMN 3-TIME VS CONCENTRATION FOR CONDUCTIVITY, ACIDITY, IRON & pH

FIGURE XXIII



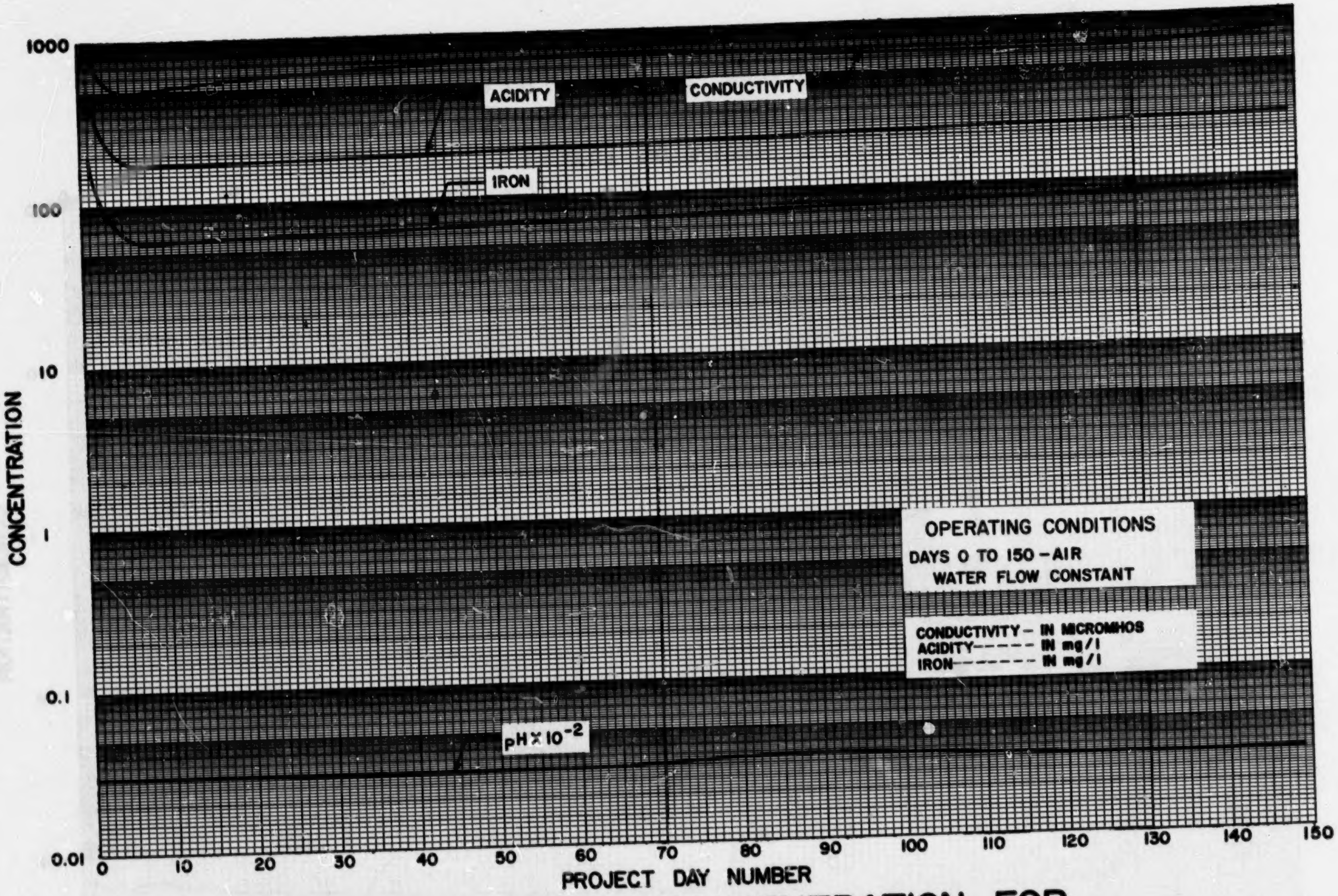
COLUMN 4 - TIME VS CONCENTRATION FOR CONDUCTIVITY, ACIDITY, IRON & pH

FIGURE XXIV



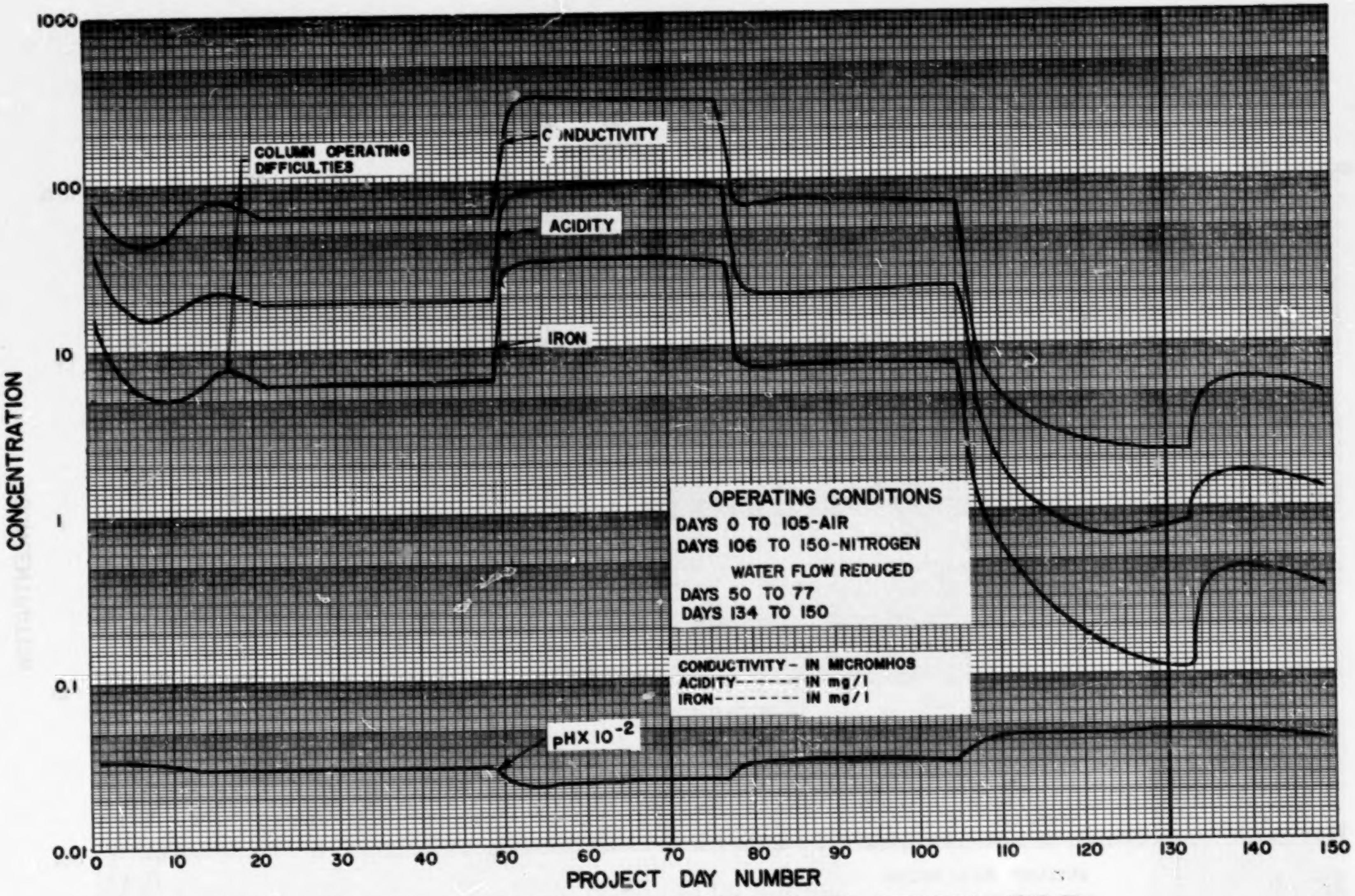
COLUMN 5 - TIME VS CONCENTRATION FOR CONDUCTIVITY, ACIDITY, IRON & pH

FIGURE XXV



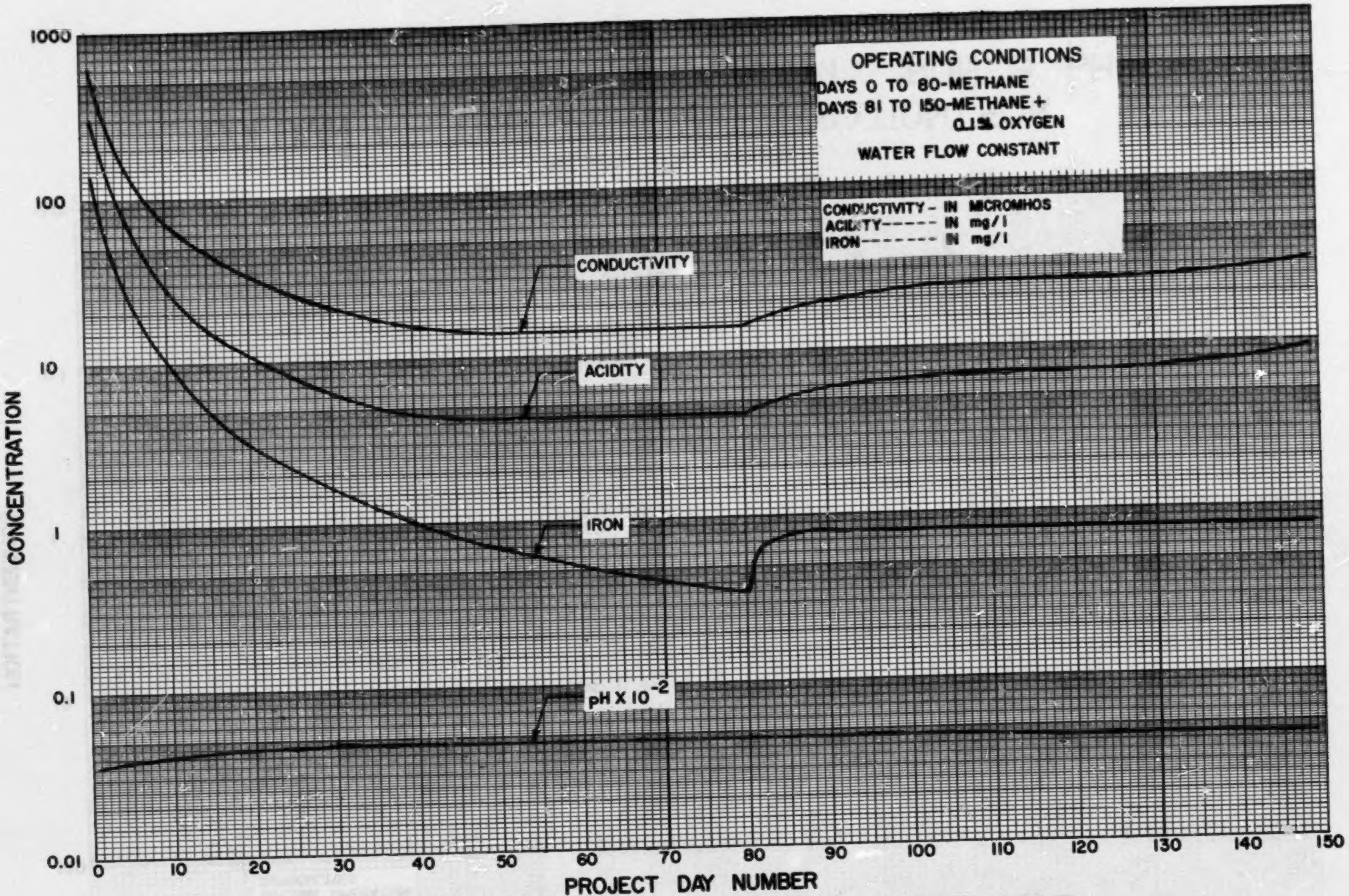
COLUMN 6 - TIME VS CONCENTRATION FOR CONDUCTIVITY, ACIDITY, IRON & pH

FIGURE XXVI



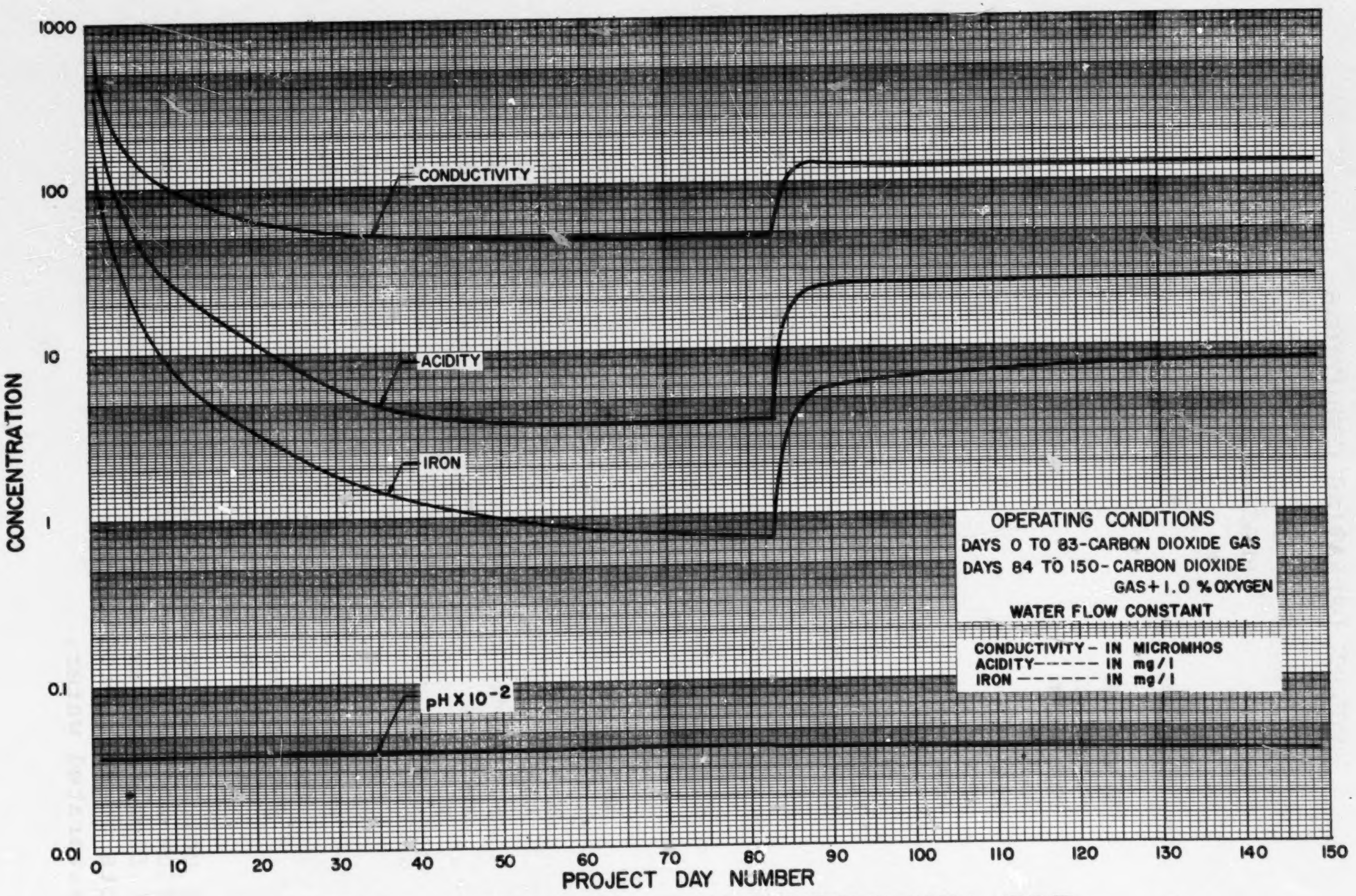
COLUMN 7 - TIME VS CONCENTRATION FOR CONDUCTIVITY, ACIDITY, IRON & pH

FIGURE XXVII



COLUMN 8 – TIME VS CONCENTRATION FOR CONDUCTIVITY, ACIDITY, IRON & pH

FIGURE XXVIII



COLUMN 9 - TIME VS CONCENTRATION FOR CONDUCTIVITY, ACIDITY, IRON & pH

FIGURE XXIX

TABLE I

COLUMN OPERATING CONDITIONS

PHASE I

Column	Gas	Gas Flow cc/minute	Water Flow ml/minute
1	Nitrogen	45	8.5
2	Nitrogen	45	8.5
3(1)	Nitrogen	45	8.5
4	Air	45	8.5
5	Air	45	8.7
6(1)	Air	45	8.5
7	Air	45	8.5(3) 1.8 8.5
8	Methane	45(2)	8.5
9	Carbon Dioxide	45	8.5

PHASE II

Column	Gas	Gas Flow cc/minute	Water Flow ml/minute
1	Nitrogen + 0.5% Oxygen	45	8.5
2	Nitrogen	45	8.5(4)
3(1)	Nitrogen	45	8.5
4	Nitrogen	45	8.5
5	Methane	30	8.7
6(1)	Air	45	8.5
7	Nitrogen	45	8.5(3) 1.8 8.5
8	Methane + 0.1% Oxygen	45	8.5
9	99% Carbon Dioxide 1% Oxygen	30	8.5

(1) These columns serve as controls.

(2) Gas Flow was decreased to 30 cc/minute on project day 63.

(3) Water flow rate was varied in order to determine the effects on acid production.

(4) Air saturated water.

TABLE II

COLUMN GAS AND WATER FLOW DATA

Column	Gas Flow Rate (cc/minute)		Water Flow Rate (ml/minute)		Column Temp. (°F)		Dissolved Oxygen In Feedwater(1)	
	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
1	45	45	8.5	8.5	55	55	0	0
2	45	45	8.5	8.5	55	55	0	8.5
3	45	45	8.5	8.5	55	55	0	0
4	45	45	8.5	8.5	55	55	0	0
5	45	30	8.7	8.7	55	55	0	0
6	45	45	8.5	8.5	55	55	0	0
7	45	45	8.5(2)	8.5(2)	55(3)	55(3)	0	0
8	45(4)	45	8.5	8.5	55	55	0	0
9	45	30	8.5	8.5	55	55	0	0

(1) A deaerator drain line problem occurred on project day 136 causing an increase in the dissolved oxygen concentration of approximately 1.0 ppm. This condition was corrected on project day 141.

(2) The water flow rate was reduced to 1.8 ml/minute on project day 49, returned to 8.5 ml/minute on project day 77 and reduced again to 1.8 ml/minute on project day 133 in order to study the effects of water flow rate on acid production.

(3) The reduced water flow rate (refer to (2) above) resulted in an effluent water temperature of approximately 65°F. This value, which is higher than expected, is believed to be due to the increased detention time in the effluent water receiving vessel rather than the actual effluent water temperature.

(4) The gas reserve became very low on project day 63 and the gas flow rate was decreased to 30 cc/minute and remained at this rate through project day 81.

TABLE III

PYRITE ANALYSIS

A sample of ground iron pyrite was examined by X-ray diffraction and iron pyrites, FeS_2, was identified as the principal crystalline component.

Five very weak lines could not be assigned. The intensity of the pyrite pattern indicates that probably at least 75% of the sample is pyrite.

A portion of the sample was heated to about 500°C overnight to convert it to the oxide form. The weight loss was 38.06%. Semi-quantitative spectrochemical analysis of the ignited sample revealed the following information:

Element	Approximate %
Fe	25
Si	1
Al	0.1
Mn	0.05
Ti	0.03
Ca,Cu,Ni,Sn	Traces (less than 0.01%)

The following elements were looked for but not found: Ag, As, B, Ba, Be, Fi, Cd, Co, Cr, Hg, Mg, Mo, Na, Pb, Sb, V, Zn, and Zr.

TABLE IV

INFLUENT GAS ANALYSES
MANUFACTURERS SPECIFICATIONS

	Constituent Gases			
Cylinder Gas	N_2	CO_2	CH_4	O_2
Nitrogen(1)	99.5	0.002	-	0.02
Carbon Dioxide(1)	Trace	99.8	-	0.05
Methane(1)	-	-	99.5	0.05
Air(1)	78.9	0.03	-	20.9
Nitrogen + 0.5% Oxygen(2)	99.477	-	-	.5230
Methane + 0.1% Oxygen(3)	-	-	99.8875	.1125
Carbon Dioxide + 1% Oxygen(4)	-	98.9300	-	1.0700

(1) Manufacturers minimum guaranteed purity

(2) Certified Analytical Report Lab. No. 56-10579-70 (Air Products and Chemicals, Inc.)

(3) Certified Analytical Report Lab. No. 56-10628-70 (Air Products and Chemicals, Inc.)

(4) Certified Analytical Report Lab. No. 56-11982-70 (Air Products and Chemicals, Inc.)

NOTE: The percentage not accounted for in the above analyses is composed of varying amounts of argon, ethane, propane and higher hydrocarbons and water

TABLE V

ANALYSIS OF THE VARIANCE OF EFFLUENT TOTAL IRON CONCENTRATION BETWEEN NITROGEN BLANKETED PYRITE COLUMNS(1)

Time Period - Project Day 54 through 73(2)

Means -	Column 1 (Phase I - Nitrogen).	0.445 ppm of Fe
	Column 2 (Phase I - Nitrogen).	0.490 ppm of Fe
	Column 3 (Phase I - Nitrogen).	0.475 ppm of Fe

Computation:

	Sum of Squares	df	Mean Square	F Ratio
Between	0.02	2	.01	$F = \frac{.01}{.005} = 2.0$
Within	0.27	57	.005	$F_{.05}$ (2,57) = 3.16
Total	0.29	59		$F_{.01}$ (2,57) = 5.0

Conclusion: There is not a significant difference between the effluent total iron concentrations from pyrite under nitrogen atmospheres at either the 5% or 1% level of significance.

Note: (1) Total iron was chosen as the test parameter because of the high degree of accuracy of the total iron analysis.
(2) The time period used is believed to represent a near steady state of acid production.

TABLE VI

ANALYSIS OF THE VARIANCE OF EFFLUENT TOTAL IRON CONCENTRATION BETWEEN AIR BLANKETED PYRITE COLUMNS(1)

(Columns 4 & 6)

Time Period - Project Day 54 through 73(2)

Means - Column 4 (Phase I - Air). . . . . .77.3 ppm of Fe
Column 6 (Phase I - Air). . . . . .69.5 ppm of Fe

Computation:

	Sums of Squares	df	Mean Square	F Ratio
Between	608.4	1	608.40	$F = \frac{608.40}{980.72} = .620$
Within	37267.2	38	980.72	$F_{.05}\ (1,38) = 4.10$
Total	37875.6	39		$F_{.01}\ (1,38) = 7.35$

Conclusion: There is not a significant difference between the effluent total iron concentrations from pyrite under air atmospheres in Columbus 4 and 6 at either the 5% or 1% level of significance.

Note: (1) Total iron was chosen as the test parameter because of the high degree of accuracy of the total iron analysis.
(2) The time period used is believed to represent a near steady state of acid production.

TABLE VII

ANALYSIS OF THE VARIANCE OF EFFLUENT TOTAL IRON CONCENTRATION BETWEEN AIR BLANKETED PYRITE COLUMNS(1)

(Columns 4, 5, & 6)

Time Period - Project Day 54 through 73(2)

Means - Column 4 (Phase I - Air). . . . . 77.3 ppm of Fe
Column 5 (Phase I - Air). . . . . 65.2 ppm of Fe
Column 6 (Phase I - Air). . . . . 69.5 ppm of Fe

Computation:(3)

	Sum of Squares	df	Mean Square	F Ratio
Between	.082	2	.041	$F = \frac{.041}{.003} = 13.67$
Within	.17	56	.003	$F_{.05}$ (2,56) = 3.17
Total	.252	58		$F_{.01}$ (2,56) = 5.01

Conclusion: There is a significant difference between the effluent total iron concentrations from pyrite under air atmospheres in Columbus 4, 5, and 6 at both the 5% and 1% level of significance.

Note:
(1) Total iron was chosen as the test parameter because of the high degree of accuracy of the total iron analysis.
(2) The time period used is believed to represent a near steady state of acid production.
(3) The computation was based on the mg of iron per minute as adjusted for variations in the water flow rate.

TABLE VIII

ANALYSIS OF THE VARIATION OF EFFLUENT TOTAL IRON CONCENTRATION BETWEEN AN AIR BLANKETED CONTROL COLUMN IN PHASE I AND PHASE II(1)

Time Period - Project day 59 through 73 in Phase I and 120 through 134 in Phase II(2)

Means - Phase I - Air . . . . 70.63 ppm of Fe
Phase II - Air. . . . . 82.77 ppm of Fe

Computation:

	Sum of Squares	df	Mean of Square	F Ratio
Between	1096.87	1	1096.87	$F = \frac{1096.87}{497.30} = 2.21$
Within	13924.48	28	497.30	$F_{.05}$ (1,28) = 4.20
Total	15021.35	29		$F_{.01}$ (1,28) = 7.66

Conclusion: There is not a significant difference between the effluent total iron concentration in Phase I and Phase II of an air blanketed column at either the 5% or 1% level of significance indicating that a steady state of acid production has been reached.

Note: (1) Total iron was chosen as the test parameter because of the high degree of accuracy of the total iron analysis.

(2) The time period used is believed to represent a near steady state of acid production.

TABLE IX

ANALYSIS OF THE VARIANCE OF EFFLUENT TOTAL IRON CONCENTRATION BETWEEN NITROGEN AND METHANE BLANKETED PYRITE COLUMNS IN PHASE I(1)

Time Period - Project day 54 through 73(2)

Means - Column 1 (Nitrogen). . . . . .0.445 ppm of Fe
Column 2 (Nitrogen). . . . . .0.490 ppm of Fe
Column 3 (Nitrogen). . . . . .0.475 ppm of Fe
Column 8 (Methane) . . . . .0.520 ppm of Fe

Computation:

	Sum of Squares	df	Mean Square	F Ratio
Between	0.06	3	0.02	$F = \frac{0.02}{0.005} = 4.0$
Within	0.36	76	0.005	$F_{.05}$ (3,76) = 2.74
Total	0.42	79		$F_{.01}$ (3,76) = 4.09

Conclusion: There is a significant difference in the total iron concentration between nitrogen and methane atmospheres at the 5% but not at the 1% level of significance.

Note: (1) Total iron was chosen as the test parameter because of the high degree of accuracy of the total iron analysis.
(2) The time period used is believed to represent a near steady state of acid production.

TABLE X

ANALYSIS OF THE VARIANCE OF EFFLUENT TOTAL IRON CONCENTRATION BETWEEN NITROGEN BLANKETED PYRITE COLUMNS IN PHASE I AND A NITROGEN BLANKETED PYRITE COLUMN IN PHASE II WHICH HAD ORIGINALLY BEEN UNDER AN AIR ATMOSPHERE(1)(2)

Time Period - Project Day 43 through 57 for Columns 1, 2, and 3 and Project Day 120 through 134 for Column 4(3)

Means - Column 1 (Phase I - Nitrogen) . . . . .0.600 ppm of Fe
Column 2 (Phase I - Nitrogen) . . . . .0.679 ppm of Fe
Column 3 (Phase I - Nitrogen) . . . . .0.686 ppm of Fe
Column 4 (Phase II - Nitrogen). . . . . .0.552 ppm of Fe

Computation:

	Sum of Squares	df	Mean Square	F Ratio
Between	.18	3	.06	$F = \frac{0.6}{0.12} = 5.0$
Within	.62	53	.012	$F_{.05}\ (3,53) = 2.79$
Total	.80	56		$F_{.01}\ (3,53) = 4.20$

Conclusion: There is a significant difference between the effluent total iron concentration from pyrite under a nitrogen atmosphere in Phase I and pyrite under a nitrogen atmosphere in Phase II at both the 5% and 1% level of significance.

TABLE IX

ANALYSIS OF THE VARIANCE OF EFFLUENT TOTAL IRON CONCENTRATION BETWEEN NITROGEN AND METHANE BLANKETED PYRITE COLUMNS IN PHASE I(1)

Time Period - Project day 54 through 73(2)

Means - Column 1 (Nitrogen). . . . . .0.445 ppm of Fe
Column 2 (Nitrogen). . . . . .0.490 ppm of Fe
Column 3 (Nitrogen). . . . . .0.475 ppm of Fe
Column 8 (Methane) . . . . .0.520 ppm of Fe

Computation:

	Sum of Squares	df	Mean Square	F Ratio
Between	0.06	3	0.02	$F = \frac{0.02}{0.005} = 4.0$
Within	0.36	76	0.005	$F_{.05}$ (3,76) = 2.74
Total	0.42	79		$F_{.01}$ (3,76) = 4.09

Conclusion: There is a significant difference in the total iron concentration between nitrogen and methane atmospheres at the 5% but not at the 1% level of significance.

Note: (1) Total iron was chosen as the test parameter because of the high degree of accuracy of the total iron analysis.
(2) The time period used is believed to represent a near steady state of acid production.

TABLE X

ANALYSIS OF THE VARIANCE OF EFFLUENT TOTAL IRON CONCENTRATION BETWEEN NITROGEN BLANKETED PYRITE COLUMNS IN PHASE I AND A NITROGEN BLANKETED PYRITE COLUMN IN PHASE II WHICH HAD ORIGINALLY BEEN UNDER AN AIR ATMOSPHERE(1)(2)

Time Period - Project Day 43 through 57 for Columns 1, 2, and 3 and Project Day 120 through 134 for Column 4(3)

Means - Column 1 (Phase I - Nitrogen) . . . . .0.600 ppm of Fe
Column 2 (Phase I - Nitrogen) . . . . .0.679 ppm of Fe
Column 3 (Phase I - Nitrogen) . . . . .0.686 ppm of Fe
Column 4 (Phase II - Nitrogen). . . . . .0.552 ppm of Fe

Computation:

	Sum of Squares	df	Mean Square	F Ratio
Between	.18	3	.06	$F = \frac{0.6}{0.12} = 5.0$
Within	.62	53	.012	$F_{.05}\ (3,53) = 2.79$
Total	.80	56		$F_{.01}\ (3,53) = 4.20$

Conclusion: There is a significant difference between the effluent total iron concentration from pyrite under a nitrogen atmosphere in Phase I and pyrite under a nitrogen atmosphere in Phase II at both the 5% and 1% level of significance.

TABLE X (Continued)

Note:
(1) Total iron was chosen as the test parameter because of the high degree of accuracy of the total iron analysis.
(2) Column 4 was under an air atmosphere in Phase I and a nitrogen atmosphere in Phase II.
(3) Project days 120 through 134 were chosen for Phase II since this represents a near steady state of acid production and a period when most daily samples were analyzed. Project days 43 through 57 were chosen for Phase I in order to match the Phase day of operation.

TABLE XI

ANALYSIS OF THE VARIANCE OF EFFLUENT TOTAL IRON CONCENTRATION BETWEEN METHANE AND CARBON DIOXIDE BLANKETED COLUMNS(1)

Time Period - Project days 54 through 73(2)

Means - Column 8 (Phase I - Methane) . . . . .0.52 ppm of Fe
Column 9 (Phase I - Carbon Dioxide). . . . . .0.795 ppm of Fe

Computation:

	Sum of Squares	df	Mean Square	F Ratio
Between	.759	1	.759	$F = \frac{.759}{.018} = 42.17$
Within	.681	38	.018	$F_{.05}$ (1,38) = 4.10
Total	1.440	39		$F_{.01}$ (1,38) = 7.35

Conclusion: There is a significant difference between the variance of effluent total iron concentrations from pyrite under a methane and a carbon dioxide atmosphere at both the 5% and 1% level of significance.

Note: (1) Total iron was chosen as the test parameter because of the high degree of accuracy of the total iron analysis.
(2) The time period used is believed to represent a near steady state of acid production.

TABLE XII

ANALYSIS OF THE VARIANCE OF EFFLUENT TOTAL IRON CONCENTRATION BETWEEN METHANE AND NITROGEN BLANKETED COLUMNS FOLLOWING STEADY STATE OPERATION IN AN AIR ATMOSPHERE(1)

Time Period - Project days 120 through 134(2)

Means - Column 4 (Phase II - Nitrogen). . . . . .545 ppm of Fe
Column 5 (Phase II - Methane) . . . . .533 ppm of Fe

Computation:

	Sum of Squares	df	Mean Square	F Ratio
Between	.02	1	.02	$F = \frac{.02}{.046} = .435$
Within	.65	27	.046	$F_{.05}\ (1,27) = 4.21$
Total	.67	28		$F_{.01}\ (1,27) = 7.68$

Conclusion: There is no significant difference between the variance of effluent total iron concentration from pyrite under a nitrogen and methane atmosphere following a steady state of acid production in an air atmosphere.

Note: (1) Total iron was chosen as the test parameter because of the high degree of accuracy of the total iron analysis.
(2) Project days 120 through 134 were chosen in Phase II since this represents a near steady state of acid production and a period when most daily samples were analyzed.

TABLE XIII

OPERATING LOG

Project Day	Date	Remarks
	7/14	Project start-up All columns were alternately flooding to a depth of 6-8" and siphoning
1	7/15	Water trap to column No. 9 was broken Gas flow was increased from 8 to 13 cc/min
2	7/16	Gas flow in air columns (4, 5, 6 and 7) was increased to 86 cc/min
5	7/19	Gas flows were readjusted to 15 cc/min in the inert columns (1, 2, 3, 8 and 9) and 80 cc/min in the air columns (4, 5, 6 and 7)
11	7/25	Column No. 7 was modified to eliminate the shallow flooding noted earlier (refer to Figure II)
15	7/29	Gas flow to all columns readjusted to 45 cc/min
16	7/30	Column Nos. 6, 7 and 9 were modified as column No. 7 Insulation on the effluent water trap was removed from these columns for observation purposes
17	7/31	All remaining columns were modified as column No. 7 All effluent water trap insulation was removed for observation purposes
18	8/1	Column No. 5 continued to flood to a depth of 8-10"

TABLE XIII (Continued)

Project Day	Date	Remarks
20	8/3	The tygon tubing connecting the gas separator and column discharge line was found to be leaking in column Nos. 1, 2, 5 and 7 (replacement of this tubing eliminated the flooding condition previously noted in column No. 5)
28	8/11	The primary water trap to column No. 5 was broken
48	8/31	Primary deionizer exhausted
49	9/1	Water flow to column No. 7 was decreased by 80%
57	9/9	Water sample for column No. 5 was accidently discarded
63	9/15	Gas flow in column No. 8 was decreased to 30 cc/min for remainder of Phase I
70	9/22	Coal particles in column No. 8 water separator caused effluent water to discharge through the effluent gas line rather than the sample receiving flask
77	9/29	Operational problems with the chiller control unit Water flow to column No. 7 increased to original flow rate Column No. 4 changed to Phase II atmosphere
80	10/2	Column Nos. 1, 5 and 8 changed to Phase II atmospheres
81	10/3	Gas flow to column No. 5 decreased to 30 cc/min
83	10/5	Column No. 9 changed to Phase II atmosphere

TABLE XIII (Continued)

Project Day	Date	Remarks
84	10/6	Column No. 2 changed to Phase II conditions (aerated feedwater)
92	10/14	Primary deionizer exhausted
94	10/16	Project pH meter inoperative - pH's were recorded from any one of three alternate meters during the period October 16-26, 1970
105	10/27	Column No. 7 changed from air to nitrogen atmosphere
106	10/28	Gas supply to column No. 9 became low resulting in decreased flow rates during the period October 28 - November 2, 1970
108	10/30	Primary deionizer exhausted
111	11/2	Column No. 9 gas cylinder replaced
113	11/4	Operational problems with the chiller control unit
125	11/16	Project conductivity meter inoperative - conductivities were recorded on an alternate meter during the period November 16 to 23, 1970
128	11/19	Primary deionizer exhausted
133	11/24	Water flow to column No. 7 decreased by 80%
136	11/27	Deaerator problems resulting in abnormally high dissolved oxygen concentration in the column feedwater

TABLE XIII (Continued)

Project Day	Date	Remarks
137	11/28	Project pH meter inoperative - pH's were recorded from any one of three alternate meters during the period November 28 - December 10, 1970
141	12/2	Column No. 8 atmosphere changed from CH_4 + 0.11% O_2 to N_2 + 0.52% O_2 Deaerator drain line problem corrected - dissolved oxygen concentration returned to 0 ppm
149	12/10	Deionized water supply interrupted Phase II terminated

TABLE XIV

ACID PRODUCTION, IRON PRODUCTION AND CONDUCTIVITY AS A FUNCTION OF OXYGEN CONTENT OF CARRIER GAS

Column	Time Period of Data Project Days	Carrier Gas	Oxygen Content %	Iron ppm	Acidity ppm	Conductivity micromhos
6	111-139	N_2 (Air)	20.9	82	230	691
9	111-138	CO_2	1.07	8.2	29	127
1	111-138	N_2	0.523	3.1	15.8	67
8	111-138	CH_4	0.11	0.72	6.8	24
5	111-138	CH_4	0.05	0.61	4.7	11
9	51-83	CO_2	0.05	0.8	3.9	28
3	111-138	N_2	0.02	0.23	2.3	8.4

TABLE XV

CATION-ANION BALANCE AIR CONTROL COLUMN NO. 6

Time Period - Project Days 111 through 132(1)

CATIONS

	ppm Ion	Factor To $CaCO_3$ Equivalent	ppm as $CaCO_3$
Calcium (Ca)	0.698	2.500	1.745
Magnesium (Mg)	0.085	4.100	0.349
Iron Total (Fe)	82.140	1.790	147.031
Manganese (Mn)	0.035	1.820	0.064
Aluminum (Al)	0.168	3.704	0.622
Hydrogen (H)	1.008	50.000	50.400
		Total Cations	200.211

ANIONS

	ppm Ion	Factor To $CaCO_3$ Equivalent	ppm as $CaCO_3$
Sulfate (SO_4)	208.180	1.040	216.507
		Total Anions	216.507

(1) This time period was chosen since it represents a near steady state of acid production and a period when most daily samples were analyzed.

TABLE XVI

COLUMN NO. 1
PHASE I - NITROGEN GAS
ANALYTICAL AND OTHER DATA

Day Of Operation						
Project	Phase I	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
1	1	3.30	480	272	114.0	235.0
2	2	3.50	285	150	55.7	113.0
3	3	3.80	220	96	41.0	71.8
4	4	3.90	160	68	27.2	56.5
5	5	3.95	140	60	21.5	23.0
6	6	4.00	120	44	17.0	40.0
7	7	4.10	95	36	14.6	35.7
8	8	4.05	75	28	10.3	25.8
9	9	4.15	70	26	8.2	16.6
10	10	4.20	63	22	7.4	15.8
11	11	4.10	56	20	6.7	14.3
12	12	4.15	47	18	5.7	13.9
13	13	4.20	45	16	4.9	1.4
14	14	4.25	47	16	4.5	1.4
15	15	4.10	45	14	4.2	12.2
16	16	4.20	43	14	3.9	11.7
17	17	4.25	38	11	3.9	11.9
18	18	4.20	42	13	4.0	2.5
19	19	4.25	35	11	3.3	3.7
20	20	4.25	31	9	2.7	6.9
21	21	4.25	27	9	2.6	7.1
22	22	4.40	35	10	2.4	3.3
23	23	4.00	28	10	2.2	3.7
24	24	4.30	26	9	2.0	10.0
25	25	4.35	23	8	1.9	10.0
26	26	4.45	22	8	1.7	1.0
27	27	4.45	22	6	1.8	1.0
28	28	4.55	23	6	1.6	1.0
29	29	4.55	20	6	1.5	1.0
30	30	4.50	20	6	1.5	13.2
31	31	4.55	19	6	1.3	5.3
32	32	4.55	18	6	1.3	13.2
33	33	4.55	18	5	1.2	8.8
34	34	4.55	18	5	1.2	1.0
35	35	4.50	17	5	1.1	5.7
36	36	4.65	16	4	1.0	9.3
37	37	4.55	16	5	1.0	9.1
38	38	4.55	15	6	1.1	1.0

TABLE XVI (Continued)

COLUMN NO. 1
PHASE I - NITROGEN GAS
ANALYTICAL AND OTHER DATA

Day Of Operation			Sp.	Hot Acid		
Project	Phase I	pH	Cond. mmhos	as $CaCO_3$	Iron as Fe	Sulfate as SO_4
39	39	4.60	15	4	1.0	7.6
40	40	4.60	14	4	1.0	6.0
41	41	4.60	14	4	0.9	1.0
42	42	4.60	13	4	0.8	6.6
43	43	4.65	13	4	0.7	1.0
44	44	4.65	13	5	0.7	2.6
45	45	4.70	13	5	0.7	1.2
46	46	4.60	13	4	0.6	1.0
47	47	4.60	13	4	0.7	11.3
48	48	4.27	21			
49	49	4.60	14	3	0.6	6.5
50	50	4.70	13	4	0.6	7.0
51	51	4.75	14	4	0.6	1.0
52	52	4.70	13	4	0.6	1.0
53	53	4.60	13	4	0.6	8.9
54	54	4.70	12	5	0.5	1.0
55	55	4.75	12	5	0.5	1.0
56	56	4.75	11	5	0.5	8.0
57	57	4.75	11	4	0.5	2.5
58	58	4.70	12	3	0.5	5.0
59	59	4.70	12	4	0.5	1.0
60	60	4.70	12	4	0.5	5.0
61	61	4.70	11	4	0.5	1.0
62	62	4.75	11	4	0.4	1.0
63	63	4.80	11	4	0.4	1.3
64	64	4.60	16	6	0.5	1.0
65	65	4.75	12	6	0.4	1.5
66	66	5.00	12	5	0.4	6.1
67	67	4.85	12	5	0.4	1.0
68	68	5.05	12	4	0.4	4.1
69	69	4.85	12	5	0.4	1.0
70	70	4.80	12	4	0.4	1.0
71	71	4.80	12	4	0.4	4.2
72	72	4.80	12	5	0.4	1.0
73	73	4.80	12	5	0.4	1.0
74	74	4.95	10			
75	75	4.90	11	4	0.4	13.2
76	76	4.95	10	5	0.3	11.0

TABLE XVI (Continued)

COLUMN NO. 1
PHASE I - NITROGEN GAS
ANALYTICAL AND OTHER DATA

Day Of Operation				Hot Acid		
Project	Phase I	pH	Sp. Cond. mmhos	as $CaCO_3$	Iron as Fe	Sulfate as SO_4
77	77	5.00	9	4	0.3	4.4
78	78	5.10	9	4	0.3	1.0
79	79	4.80	12	4	0.3	2.1
80	80	4.85	11			

TABLE XVII

COLUMN NO. 2
PHASE I - NITROGEN GAS
ANALYTICAL AND OTHER DATA

Day Of Operation				Hot		
			Sp.	Acid		
			Cond.	as	Iron	Sulfate
Project	Phase I	pH	mmhos	$CaCO_3$	as Fe	as SO_4
1	1	3.30	630	284	125.0	189.0
2	2	3.50	310	180	66.3	96.3
3	3	3.80	235	108	45.5	91.6
4	4	3.85	190	76	30.7	63.2
5	5	3.90	155	64	24.4	47.2
6	6	3.95	140	52	19.2	43.8
7	7	4.10	105	52	17.2	41.6
8	8	4.00	80	34	12.3	32.7
9	9	4.10	75	28	10.4	13.4
10	10	4.00	70	24	9.3	17.4
11	11	4.10	63	22	7.6	15.0
12	12	4.15	57	22	7.4	18.4
13	13	4.10	52	20	5.8	2.9
14	14	4.05	57	18	5.5	8.6
15	15	4.00	53	18	5.3	7.5
16	16	4.10	47	17	4.7	15.2
17	17	4.25	43	13	4.2	15.1
18	18	4.10	48	16	4.9	9.2
19	19	4.10	43	13	3.5	9.9
20	20	4.20	37	15	3.1	7.3
21	21	4.30	35	10	3.0	9.5
22	22	4.20	35	12	2.6	6.9
23	23	4.35	28	10	2.4	3.1
24	24	4.30	28	11	2.2	10.0
25	25	4.35	25	7	2.1	10.0
26	26	4.45	25	10	1.9	5.1
27	27	4.45	24	8	1.9	1.0
28	28	4.45	27	8	1.9	1.0
29	29	4.45	24	8	1.7	3.4
30	30	4.45	22	6	1.8	4.1
31	31	4.60	21	6	1.5	2.7
32	32	4.55	20	6	1.4	7.8
33	33	4.45	20	6	1.3	11.2
34	34	4.40	20	6	1.3	5.4
35	35	4.40	19	5	1.3	9.5
36	36	4.55	19	5	1.2	8.3
37	37	4.50	17	5	1.1	7.0
38	38	4.50	17	7	1.2	1.0

TABLE XVII (Continued)

COLUMN NO. 2
PHASE I - NITROGEN GAS
ANALYTICAL AND OTHER DATA

Day Of Operation				Hot Acid		
Project	Phase I	pH	Sp. Cond. mmhos	as $CaCO_3$	Iron as Fe	Sulfate as SO_4
39	39	4.50	16	5	1.1	2.1
40	40	4.60	15	5	1.0	8.4
41	41	4.60	15	4	1.0	1.0
42	42	4.60	14	4	1.0	3.3
43	43	4.65	14	4	0.8	3.6
44	44	4.70	14	5	0.8	2.7
45	45	4.70	14	5	0.8	1.0
46	46	4.60	14	5	0.8	6.5
47	47	4.50	15			
48	48	4.50	15			
49	49	4.60	14	4	0.7	5.9
50	50	4.70	14	4	0.7	5.8
51	51	4.70	15	4	0.7	2.4
52	52	4.70	15	4	0.7	1.0
53	53	4.60	15	5	0.7	1.0
54	54	4.65	13	5	0.5	5.4
55	55	4.70	13	5	0.5	8.1
56	56	4.80	12	5	0.5	6.6
57	57	4.70	13	4	0.5	1.0
58	58	4.70	12	4	0.5	1.0
59	59	4.70	16	5	0.8	1.0
60	60	4.65	13	4	0.6	1.0
61	61	4.75	12	4	0.5	1.0
62	62	4.70	11	4	0.5	1.4
63	63	4.80	12	4	0.5	1.0
64	64	4.70	14	4	0.5	1.0
65	65	4.75	12	5	0.5	4.5
66	66	5.00	12	5	0.4	1.1
67	67	4.90	12	4	0.4	1.0
68	68	4.90	11	4	0.4	3.9
69	69	4.85	12	5	0.4	3.3
70	70	4.80	12	5	0.4	9.1
71	71	4.75	12	4	0.5	1.0
72	72	4.75	12	5	0.5	3.4
73	73	4.80	12	4	0.4	7.1
74	74	5.00	10			
75	75	4.90	11	4	0.4	1.0
76	76	5.00	10	5	0.4	2.5

TABLE XVII (Continued)

COLUMN NO. 2
PHASE I - NITROGEN GAS
ANALYTICAL AND OTHER DATA

Day Of Operation						
Project	Phase I	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
77	77	5.00	10	4	0.3	4.4
78	78	5.10	10	4	0.3	1.0
79	79	4.75	12	4	0.3	1.0
80	80	4.75	11			
81	81	4.90	10			
82	82	4.95	10			
83	83	5.00	10			
84	84	4.90	10			

TABLE XVIII

COLUMN NO. 3
NITROGEN GAS
ANALYTICAL AND OTHER DATA

Day of Operation	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
1	3.40	500	260	114.0	190.0
2	3.50	300	170	66.3	126.0
3	3.80	230	108	45.5	81.3
4	3.90	190	80	30.1	56.3
5	3.95	155	64	25.1	25.0
6	4.05	125	52	19.2	42.3
7	4.15	100	48	17.2	39.5
8	4.00	80	32	11.8	30.6
9	4.15	75	30	10.2	16.6
10	4.10	66	24	9.0	3.4
11	4.10	58	22	7.6	17.4
12	4.20	52	20	6.8	6.7
13	4.15	48	18	5.6	11.4
14	4.20	52	18	5.3	1.4
15	4.20	48	16	5.0	59.6
16	4.15	43	14	4.3	13.0
17	4.20	37	11	3.7	11.8
18	4.25	42	14	4.6	10.7
19	4.20	40	12	3.8	10.3
20	4.25	35	14	3.2	7.4
21	4.30	32	10	3.0	11.7
22	4.30	31	10	2.7	5.2
23	4.50	27	10	2.5	1.4
24	4.35	26	10	2.3	10.0
25	4.40	24	8	2.1	10.0
26	4.40	24	8	1.9	1.0
27	4.50	23	6	1.9	1.0
28	4.45	25	7	1.8	1.0
29	4.50	22	7	1.6	5.6
30	4.55	21	5	1.6	7.8
31	4.50	20	5	1.4	10.7
32	4.50	19	5	1.3	6.1
33	4.60	18	5	1.3	12.7
34	4.45	19	5	1.3	1.0
35	4.45	18	5	1.2	1.0
36	4.55	18	5	1.1	9.1
37	4.55	17	5	1.0	6.5
38	4.55	16	5	1.1	1.0

TABLE XVIII (Continued)

COLUMN NO. 3
NITROGEN GAS
ANALYTICAL AND OTHER DATA

Day of Operation	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
39	4.55	16	4	1.0	1.0
40	4.55	15	4	1.0	8.1
41	4.55	15	5	1.0	1.0
42	4.60	15	4	1.0	1.3
43	4.60	15	5	0.8	1.0
44	4.70	14	4	0.8	3.5
45	4.65	14	5	0.7	1.0
46	4.55	14	4	0.8	1.0
47	4.50	15			
48	4.20	22			
49	4.60	14	3	0.7	1.0
50	4.70	14	4	0.7	3.5
51	4.70	15	4	0.8	2.7
52	4.70	14	4	0.8	1.0
53	4.60	14	5	0.7	2.8
54	4.70	13	4	0.6	1.0
55	4.70	13	6	0.5	1.0
56	4.75	12	6	0.5	3.9
57	4.70	12	4	0.5	1.0
58	4.70	12	4	0.5	1.0
59	4.70	15	4	0.5	1.0
60	4.65	13	5	0.5	1.0
61	4.70	12	4	0.5	1.0
62	4.70	11	4	0.5	1.0
63	4.75	12	4	0.5	1.0
64	4.45	19	7	0.5	1.0
65	4.75	13	4	0.4	3.2
66	5.05	12	4	0.4	1.0
67	4.90	12	4	0.4	1.0
68	4.85	12	3	0.4	2.6
69	4.80	12	8	0.5	1.0
70	4.80	12	7	0.4	11.2
71	4.75	12	4	0.5	1.0
72	4.80	12	5	0.5	7.9
73	4.80	12	5	0.4	6.2
74	4.95	10			
75	4.85	11	4	0.4	1.0
76	4.95	10	4	0.4	2.6

TABLE XVIII (Continued)

COLUMN NO. 3
NITROGEN GAS
ANALYTICAL AND OTHER DATA

Day of Operation	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
77	5.00	10	4	0.3	1.0
78	5.05	10	4	0.3	1.8
79	4.75	12	4	0.3	2.5
80	4.65	12	4	0.3	1.0
81	4.90	10	4	0.4	1.0
82	4.95	10	5	0.4	1.0
83	5.00	10	4	0.3	1.0
84	4.95	10	5	0.3	1.0
85	4.95	10	5	0.3	1.0
86	4.85	10	4	0.3	1.0
87	4.80	10	4	0.3	1.0
88	4.70	10	5	0.3	1.0
89	4.95	10	4	0.3	1.3
90	4.80	10	4	0.2	1.0
91	4.65	10	4	0.3	1.0
92	4.90	10	4	0.3	12.9
93	4.75	11	4	0.3	5.3
94	4.80	9	4	0.3	1.0
95	5.00	10	3	0.3	4.4
96	5.05	10	4	0.3	14.5
97	4.90	10	5	0.3	1.0
98	4.80	10	6	0.2	11.7
99	4.95	10	3	0.3	7.1
100	5.10	9	3	0.2	1.1
101	5.00	10	6	0.3	1.0
102	5.00	10	3	0.2	5.0
103	5.00	9	4	0.2	1.0
104	4.90	8	3	0.3	2.0
105	4.95	8	3	0.3	14.3
106	4.90	9	6	0.3	8.8
107	4.90	9	3	0.3	1.0
108	4.80	15	4	0.2	1.0
109	4.70	12	4	0.4	5.9
110	4.85	10	3	0.3	1.0
111	4.80	13	4	0.3	1.0
112	4.95	9	2	0.3	1.0
113	4.90	7	5	0.3	1.0
114	4.95	7	8	0.3	8.5

TABLE XVIII (Continued)

COLUMN NO. 3
NITROGEN GAS
ANALYTICAL AND OTHER DATA

Day of Operation	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
115	4.90	10	2	0.2	7.1
116	4.95	7	8	0.2	1.4
117	4.95	9	2	0.2	1.0
118	4.95	7	5	0.2	1.0
119	5.00	9	1	0.2	3.1
120	5.00	7	2	0.2	9.2
121	4.95	8	3	0.2	17.6
122	4.95	8	4	0.2	5.4
123	4.95	8	2	0.2	14.0
124	5.00	8	4	0.2	6.7
125	4.85	8	2	0.3	8.3
126	4.95	8	2	0.2	1.0
127	5.00	8	3	0.2	1.7
128	4.85	10	3	0.2	1.0
129	4.95	9	3	0.2	1.4
130	4.95	8	4	0.2	7.0
131	4.95	8	3	0.2	11.5
132	4.85	8	4	0.2	8.6
133	4.75	8	4	0.2	4.7
134	5.00	10	3	0.3	4.4
135	-	-	-	-	-
136	5.00	9	5	0.3	1.0
137	5.00	8	4	0.3	1.5
138	-	-	-	-	-
139	4.80	13	5	0.4	1.0
140	4.50	9	2	0.4	1.0
141	5.00	8	3	0.4	5.3
142	4.95	9	2	0.2	4.8
143	-	-	-	-	-
144	-	-	-	-	-
145	-	-	-	-	-
146	4.95	11	4	0.2	8.9
147	5.00	9	3	0.2	6.9
148	5.00	9	4	0.2	6.2
149	4.70	12	5	0.3	14.9

TABLE XIX

COLUMN NO. 4
PHASE I - AIR
ANALYTICAL AND OTHER DATA

Day Of Operation			Sp. Cond.	Hot Acid	Iron	Sulfate
Project	Phase I	pH	mmhos	as $CaCO_3$	as Fe	as SO_4
1	1	3.00	900	420	175.0	247.0
2	2	3.20	550	264	108.0	236.0
3	3	3.30	500	200	79.2	192.0
4	4	3.20	520	176	67.4	183.0
5	5	3.25	490	176	61.4	151.0
6	6	3.25	485	168	56.2	155.0
7	7	3.35	425	160	56.9	142.0
8	8	3.10	420	136	50.4	139.0
9	9	3.20	420	148	49.4	122.0
10	10	3.05	490	140	49.6	95.1
11	11	3.05	505	152	48.3	82.5
12	12	3.10	500	152	50.4	114.0
13	13	3.05	550	152	51.1	80.9
14	14	3.00	580	160	52.4	127.0
15	15	2.95	555	156	53.7	128.0
16	16	2.95	540	158	51.0	152.0
17	17	3.05	515	152	50.5	136.0
18	18	2.90	740	211	69.1	197.0
19	19	2.85	710	209	65.3	185.0
20	20	2.85	680	201	67.6	174.0
21	21	2.95	640	185	65.1	179.0
22	22	2.90	659	189	63.7	174.0
23	23	2.90	610	201	61.6	175.0
24	24	2.95	636	193	64.1	180.0
25	25	2.95	620	193	62.2	163.0
26	26	2.90	640	189	61.6	176.0
27	27	3.00	620	193	63.1	176.0
28	28	2.90	645	185	65.5	180.0
29	29	2.90	650	193	66.2	172.0
30	30	2.90	650	228	64.0	179.0
31	31	2.90	640	188	66.0	172.0
32	32	2.95	655	200	64.0	181.0
33	33	2.95	650	212	66.0	180.0
34	34	2.85	670	200	67.0	190.0
35	35	2.95	635	196	67.0	179.0
36	36	2.90	645	188	68.0	188.0
37	37	2.85	630	200	66.0	184.0
38	38	2.85	615	184	65.0	172.0

TABLE XIX (Continued)

COLUMN NO. 4
PHASE I - AIR
ANALYTICAL AND OTHER DATA

Day Of Operation						
Project	Phase I	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
39	39	2.90	630	196	67.0	183.0
40	40	2.90	620	192	66.0	175.0
41	41	2.95	630	196	67.0	183.0
42	42	2.95	605	192	66.0	180.0
43	43	2.90	630	204	70.0	186.0
44	44	2.90	630	200	67.0	183.0
45	45	2.90	640	200	67.0	179.0
46	46	2.90	645	196	66.0	182.0
47	47	2.90	650			
48	48	2.95	690			
49	49	2.95	655	192	67.5	173.0
50	50	2.90	710	217	75.0	195.0
51	51	2.90	750	228	76.0	217.0
52	52	2.80	760	228	79.0	217.0
53	53	2.85	710	220	78.0	209.0
54	54	2.90	680	208	86.0	196.0
55	55	2.90	660	196	87.0	191.0
56	56	2.85	655	192	86.0	188.0
57	57	2.90	660	200	71.0	187.0
58	58	2.90	670	200	72.0	198.0
59	59	2.70	1065	264	112.0	245.0
60	60	2.85	825	250	76.0	225.0
61	61	2.85	755	220	76.0	210.0
62	62	2.85	750	220	73.0	203.0
63	63	2.90	760	208	68.0	203.0
64	64	2.85	820	208	71.5	204.0
65	65	2.90	830	212	72.0	202.0
66	66	3.25	850	204	72.0	202.0
67	67	3.05	840	208	69.0	199.0
68	68	3.05	850	204	72.0	200.0
69	69	3.00	845	212	71.0	196.0
70	70	3.00	780	220	76.0	209.0
71	71	2.95	810	224	77.0	212.0
72	72	2.90	875	232	82.0	233.0
73	73	2.95	820	224	76.0	213.0
74	74	3.05	705			
75	75	3.00	745	212	74.0	190.0
76	76	3.05	705	204	69.0	192.0
77	77	3.05	650	192	66.0	182.0

TABLE XX

COLUMN NO. 5
PHASE I - AIR
ANALYTICAL AND OTHER DATA

Day Of Operation		pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
Project	Phase I					
1	1	2.95	840	440	181.0	381.0
2	2	3.10	560	264	109.0	254.0
3	3	3.20	480	204	81.9	188.0
4	4	3.25	510	180	68.4	147.0
5	5	3.25	495	172	63.5	111.0
6	6	3.30	475	172	58.5	146.0
7	7	3.30	440	156	56.9	140.0
8	8	3.15	420	148	49.3	128.0
9	9	3.10	415	144	47.8	94.4
10	10	3.05	480	140	48.4	88.9
11	11	3.10	495	148	51.5	107.0
12	12	3.00	500	152	51.6	110.0
13	13	3.00	540	152	49.5	62.4
14	14	2.95	575	156	51.6	106.0
15	15	3.00	560	152	52.6	130.0
16	16	2.95	520	148	49.8	142.0
17	17	3.00	510	140	49.5	136.0
18	18	3.00	500	129	42.0	121.0
19	19	3.15	350	98	29.1	83.6
20	20	3.30	255	70	21.2	58.9
21	21	3.05	505	156	53.5	143.0
22	22	2.90	570	168	54.5	151.0
23	23	3.05	550	160	56.1	151.0
24	24	3.05	570	168	56.7	153.0
25	25	2.90	570	176	56.7	147.0
26	26	2.90	575	176	56.4	152.0
27	27	2.90	570	164	56.3	150.0
28	28	2.90	600	181	58.2	159.0
29	29	2.95	605	176	57.0	155.0
30	30	2.90	605	172	58.0	154.0
31	31	2.95	600	136	56.0	148.0
32	32	3.00	600	172	58.0	157.0
33	33	2.95	600	172	57.0	158.0
34	34	2.85	620	172	59.0	167.0
35	35	2.90	590	172	58.0	154.0
36	36	2.90	600	180	59.0	162.0
37	37	2.85	580	176	60.0	163.0
38	38	2.85	570	168	58.0	153.0

TABLE XX (Continued)

COLUMN NO. 5
PHASE I - AIR
ANALYTICAL AND OTHER DATA

Day Of Operation						
Project	Phase I	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
39	39	2.95	590	172	60.0	157.0
40	40	2.90	585	172	59.0	156.0
41	41	2.90	580	176	61.0	160.0
42	42	2.90	580	180	61.0	171.0
43	43	2.90	600	188	62.0	168.0
44	44	3.00	600	184	61.0	163.0
45	45	2.90	595	180	62.0	162.0
46	46	2.95	610	176	61.0	151.0
47	47	2.90	610			
48	48	2.85	655			
49	49	2.95	610	177	60.7	158.0
50	50	3.00	680	192	72.0	181.0
51	51	2.90	740	200	72.0	192.0
52	52	2.85	710	208	69.0	204.0
53	53	2.85	670	204	70.0	192.0
54	54	2.90	650	192	65.0	180.0
55	55	2.90	620	180	63.0	174.0
56	56	2.90	615	184	62.0	175.0
57	57	2.90	610			
58	58	2.90	600	176	64.0	179.0
59	59	2.90	650	200	66.0	173.0
60	60	2.90	650	200	64.0	183.0
61	61	2.90	670	200	65.0	182.0
62	62	2.90	675	190	65.0	180.0
63	63	2.90	680	182	62.0	180.0
64	64	2.90	770	186	63.9	180.0
65	65	2.95	720	184	62.0	182.0
66	66	3.30	770	184	63.0	181.0
67	67	3.05	750	180	63.0	174.0
68	68	3.10	745	184	63.0	180.0
69	69	3.00	745	192	63.0	181.0
70	70	3.00	710	188	71.0	183.0
71	71	3.00	735	200	70.0	189.0
72	72	3.00	740	212	74.0	203.0
73	73	3.00	735	204	70.0	192.0
74	74	3.05	640			
75	75	2.95	685	184	66.0	170.0
76	76	3.05	640	174	62.0	171.0

TABLE XX (Continued)

COLUMN NO. 5
PHASE I - AIR
ANALYTICAL AND OTHER DATA

Day Of Operation						
Project	Phase I	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
77	77	3.10	600	172	60.0	159.0
78	78	3.15	575	174	57.0	161.0
79	79	3.00	760	200	67.0	183.0
80	80	3.05	770			

TABLE XXI

COLUMN NO. 6
AIR
ANALYTICAL AND OTHER DATA

Day of Operation	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
1	2.95	962	490	196.0	362.0
2	3.10	595	276	117.0	261.0
3	3.25	525	208	79.9	230.0
4	3.25	525	188	72.4	108.0
5	3.20	490	176	64.0	166.0
6	3.20	505	168	60.6	156.0
7	3.30	440	180	58.3	148.0
8	3.10	445	144	50.5	133.0
9	3.10	435	156	50.7	128.0
10	3.05	515	170	51.2	137.0
11	3.15	500	152	52.8	109.0
12	3.00	515	160	54.2	130.0
13	2.95	570	156	53.2	99.8
14	2.90	595	156	51.6	106.0
15	2.95	590	164	56.1	157.0
16	3.00	555	160	54.1	158.0
17	3.05	455	128	43.3	112.0
18	2.85	675	194	64.1	175.0
19	2.90	650	189	64.4	170.0
20	3.00	625	180	61.6	168.0
21	2.90	600	180	58.9	164.0
22	2.90	630	185	61.0	168.0
23	2.90	570	180	61.0	160.0
24	2.95	590	176	59.8	164.0
25	2.85	595	189	61.6	162.0
26	2.95	600	176	59.8	159.0
27	3.00	590	185	60.6	163.0
28	3.00	620	177	60.6	165.0
29	2.95	630	177	60.7	164.0
30	2.95	630	204	60.0	161.0
31	2.90	610	176	61.0	162.0
32	3.00	615	180	58.0	168.0
33	2.90	610	180	61.0	165.0
34	2.90	640	180	63.0	175.0
35	2.90	600	176	62.0	171.0
36	2.90	620	184	64.0	176.0
37	2.85	605	180	64.0	177.0
38	2.85	595	176	65.0	169.0

TABLE XXI (Continued)

COLUMN NO. 6
AIR
ANALYTICAL AND OTHER DATA

Day of Operation	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
39	2.90	605	180	61.0	166.0
40	2.90	600	184	64.0	170.0
41	2.90	600	184	64.0	175.0
42	2.90	600	193	66.0	177.0
43	3.00	615	188	65.0	167.0
44	2.90	620	200	66.0	178.0
45	3.00	610	192	64.0	174.0
46	2.90	630	188	65.0	170.0
47	2.90	630			
48	2.85	680			
49	2.95	640	184	64.3	172.0
50	3.00	705	204	74.0	192.0
51	2.90	760	208	75.0	198.0
52	2.85	730	224	78.0	209.0
53	2.85	685	208	75.0	200.0
54	2.85	655	196	69.0	190.0
55	2.90	635	192	64.0	188.0
56	2.90	615	190	63.0	184.0
57	2.90	610	188	67.0	177.0
58	2.90	615	186	67.0	179.0
59	2.90	650	188	71.0	180.0
60	2.90	695	200	71.0	194.0
61	2.90	690	200	69.0	193.0
62	2.90	690	200	70.0	189.0
63	2.90	700	188	67.0	189.0
64	2.90	740	194	70.5	195.0
65	2.90	770	188	67.0	194.0
66	3.20	796	196	69.0	191.0
67	3.00	770	184	68.0	188.0
68	3.10	775	200	70.0	197.0
69	3.00	760	190	69.0	190.0
70	3.00	725	200	72.0	186.0
71	3.00	745	212	73.0	193.0
72	2.95	780	216	80.0	204.0
73	3.00	745	204	73.0	199.0
74	3.10	650			
75	2.95	695	204	73.0	180.0
76	3.10	650	194	68.0	184.0

TABLE XXI (Continued)

COLUMN NO. 6
AIR
ANALYTICAL AND OTHER DATA

Day of Operation	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
77	3.05	615	188	64.0	174.0
78	3.15	600	184	66.0	156.0
79	3.00	760	212	74.0	184.0
80	3.10	755	216	77.0	175.0
81	3.10	685	200	73.0	177.0
82	3.10	670	202	75.0	181.0
83	3.10	630	198	74.0	187.0
84	3.10	670	208	75.0	193.0
85	3.10	650	204	77.0	216.0
86	3.00	640	204	74.0	165.0
87	3.00	670	196	74.0	188.0
88	2.95	700	200	74.0	187.0
89	3.05	680	194	60.0	187.0
90	3.00	700	210	61.0	195.0
91	3.00	740	220	72.0	213.0
92	2.95	735	232	74.0	229.0
93	2.95	750	221	78.0	204.0
94	3.00	640	200	71.0	182.0
95	3.30	630	192	67.0	173.0
96	3.20	690	204	79.0	188.0
97	3.00	735	208	63.0	205.0
98	3.00	680	208	69.0	211.0
99	3.15	730	220	72.0	219.0
100	3.20	675	208	71.0	222.0
101	3.20	725	228	81.0	202.0
102	3.20	710	216	59.0	216.0
103	3.15	710	220	67.0	220.0
104	3.10	705	216	59.0	235.0
105	3.10	705	216	71.0	233.0
106	3.10	615	216	55.0	216.0
107	3.10	600	220	72.0	232.0
108	3.10	680	216	68.0	184.0
109	2.95	850	296	99.0	247.0
110	2.95	675	276	92.0	243.0
111	2.90	730	264	84.0	261.0
112	3.00	675	236	88.0	118.0
113	3.05	570	228	83.0	204.0
114	3.00	570	228	79.0	200.0

TABLE XXI (Continued)

COLUMN NO. 6
AIR
ANALYTICAL AND OTHER DATA

Day Of Operation	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
115	3.00	605	224	79.0	208.0
116	3.00	635	208	77.0	201.0
117	3.05	645	168	79.0	199.0
118	3.05	630	204	79.0	203.0
119	3.05	660	229	81.0	222.0
120	3.05	660	232	84.0	225.0
121	3.00	670	250	86.0	226.0
122	3.05	710	225	88.0	223.0
123	3.05	705	232	83.0	226.0
124	3.05	700	232	82.0	178.0
125	2.85	705	224	81.0	189.0
126	3.00	705	236	81.0	191.0
127	3.00	675	216	83.0	205.0
128	3.00	675	220	71.0	189.0
129	2.95	780	244	88.0	232.0
130	2.95	740	228	84.0	220.0
131	2.95	745	236	84.0	228.0
132	2.90	740	296	83.0	232.0
133	2.90	705	236	85.0	214.0
134	3.00	705	236	78.0	186.0
135					
136	3.00	685	216	74.0	183.0
137	2.95	790	244	87.0	200.0
138					
139	3.05	770	252	88.0	203.0
140	2.90	710	248	89.0	198.0
141	2.95	750	248	88.0	207.0
142	2.95	720	244	80.3	186.0
143					
144					
145					
146	3.00	760	244	80.0	214.0
147	2.95	760	254	90.0	239.0
148	2.95	750	246	89.0	220.0
149	2.75	840	264	94.0	240.0

TABLE XXII

COLUMN NO. 7
PHASE I - AIR
ANALYTICAL AND OTHER DATA

Day Of Operation						
Project	Phase I	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
1	1	3.10	750	370	145.0	302.0
2	2	3.10	565	252	109.0	235.0
3	3	3.25	510	216	81.2	191.0
4	4	3.50	480	180	68.4	165.0
5	5	3.25	465	168	62.0	156.0
6	6	3.25	480	160	58.2	152.0
7	7	3.30	430	152	56.2	136.0
8	8	3.10	425	140	50.1	132.0
9	9	3.10	415	140	49.3	96.3
10	10	3.05	495	170	49.3	90.1
11	11	3.10	515	152	53.2	122.0
12	12	3.05	505	192	51.7	114.0
13	13	2.85	740	204	69.0	61.5
14	14	2.85	715	208	54.2	138.0
15	15	2.85	820	240	79.3	230.0
16	16	2.75	805	228	79.3	220.0
17	17	2.80	755	212	73.4	198.0
18	18	2.80	750	217	70.8	192.0
19	19	2.85	695	203	69.1	190.0
20	20	2.85	670	197	64.4	171.0
21	21	2.90	600	176	58.0	166.0
22	22	2.90	660	189	63.1	172.0
23	23	2.85	655	197	68.4	184.0
24	24	3.00	605	185	61.6	169.0
25	25	3.00	605	185	61.0	167.0
26	26	2.90	615	185	59.8	164.0
27	27	2.90	605	185	61.9	163.0
28	28	3.00	650	189	61.9	166.0
29	29	2.85	645	181	60.7	162.0
30	30	2.90	650	180	63.0	167.0
31	31	2.90	630	176	61.0	162.0
32	32	2.95	635	184	59.0	166.0
33	33	2.90	635	184		169.0
34	34	2.85	660	192	64.0	173.0
35	35	2.90	630	180	59.0	170.0
36	36	2.90	645	188	62.0	174.0
37	37	2.85	615	200	64.0	172.0
38	38	2.85	605	184	63.0	164.0

TABLE XXII (Continued)

COLUMN NO. 7
PHASE I - AIR
ANALYTICAL AND OTHER DATA

Day Of Operation		pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
Project	Phase I					
39	39	2.85	630	188	63.0	175.0
40	40	2.90	615	184	62.0	166.0
41	41	2.90	615	180	63.0	169.0
42	42	2.90	600	184	63.0	171.0
43	43	2.90	620	188	64.0	172.0
44	44	2.90	610	188	63.0	170.0
45	45	2.90	610	192	62.0	168.0
46	46	2.90	625	192	62.0	166.0
47	47	2.90	625	188	63.0	168.0
48	48	2.90	650	180	61.2	164.0

TABLE XXIII

COLUMN NO. 7
PHASE I - AIR
(REDUCED WATER FLOW RATE)
ANALYTICAL AND OTHER DATA

Day Of Operation						
Project	Phase I	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
49	1	2.95	630	668	284.0	675.0
50	2					
51	3	2.40	2900	880	351.0	802.0
52	4	2.25	2950	884	333.0	886.0
53	5	2.25	3100	910	306.0	873.0
54	6	2.30	3050	864	293.0	835.0
55	7	2.30	3000	844	293.0	798.0
56	8	2.30	2925	818	297.0	818.0
57	9	2.25	2950	836	303.0	773.0
58	10	2.30	2900	796	295.0	
59	11	2.30	2900	932	333.0	822.0
60	12	2.30	3000	910	314.0	839.0
61	13	2.30	2975	920	315.0	846.0
62	14	2.30	2950	910	315.0	848.0
63	15	2.35	2975	888	340.0	851.0
64	16	2.30	3050	928		901.0
65	17	2.35	3250	884	325.0	875.0
66	18	2.75	3200	908	321.0	864.0
67	19	2.40	3100	932	316.0	879.0
68	20	2.55	3050	928	334.0	877.0
69	21	2.40	3250	964	325.0	859.0
70	22	2.40	3000	936	356.0	960.0
71	23	2.40	3050	984	367.0	964.0
72	24	2.40	3000	1044	367.0	985.0
73	25	2.40	3000	996	359.0	968.0
74	26	2.45	2950			
75	27	2.40	2950	984	331.0	913.0
76	28	2.45	2950	928	326.0	871.0
77	29	2.55	2450	860	301.0	828.0

TABLE XXIV

COLUMN NO. 7
PHASE I - AIR
(NORMAL WATER FLOW RATE)
ANALYTICAL AND OTHER DATA

Day Of Operation				Hot		
Project	Phase I	pH	Sp. Cond. mmhos	Acid as $CaCO_3$	Iron as Fe	Sulfate as SO4
78	1	3.10	655	184	61.0	164.0
79	2	3.00	810	214	72.0	183.0
80	3	3.05	830	212	75.0	143.0
81	4	3.10	705	180	72.0	176.0
82	5	3.10	700	208	76.0	186.0
83	6	3.10	690	204	71.0	186.0
84	7	3.10	700	198	73.0	208.0
85	8	3.10	680	212	75.0	186.0
86	9	3.00	700	208	74.0	187.0
87	10	3.05	700	204	74.0	190.0
88	11	2.95	710	208	74.0	192.0
89	12	3.05	700	196	70.0	188.0
90	13	3.00	730	208	72.0	199.0
91	14	3.00	735	224	65.0	211.0
92	15	2.95	775	244	78.0	220.0
93	16	2.95	780	229	80.0	215.0
94	17	3.00	650	200	72.0	179.0
95	18	3.30	635	180	67.0	187.0
96	19	3.20	700	222	81.0	204.0
97	20	3.00	740	212	65.0	205.0
98	21	3.05	710	220	74.0	190.0
99	22	3.15	750	224	76.0	153.0
100	23	3.20	700	240	67.0	245.0
101	24	3.10	750	220	82.0	197.0
102	25	3.10	740	220	58.0	219.0
103	26	3.10	740	216	60.0	228.0
104	27	3.05	730	212	58.0	222.0
105	28	3.05	720	228	76.0	224.0

TABLE XXV

COLUMN NO. 8
PHASE I - METHANE
ANALYTICAL AND OTHER DATA

Day Of Operation						
Project	Phase I	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
1	1	3.20	600	310	135.0	217.0
2	2	3.50	325	170	73.8	155.0
3	3	3.70	235	104	45.8	97.3
4	4	3.90	190	76	30.2	63.5
5	5	3.95	150	60	24.8	52.3
6	6	4.00	125	48	19.0	47.1
7	7	4.10	105	52	17.0	40.2
8	8	4.00	85	56	12.4	18.1
9	9	4.15	60	26	10.1	15.1
10	10	4.10	65	24	9.0	1.4
11	11	4.10	59	22	8.0	18.1
12	12	4.15	53	20	6.8	12.2
13	13	4.15	53	18	5.8	1.4
14	14	4.20	50	16	5.4	16.2
15	15	4.10	47	18	5.5	15.9
16	16	4.15	43	14	4.4	14.7
17	17	4.10	48	15	5.2	7.8
18	18	4.10	46	14	4.2	3.4
19	19	4.20	40	13	3.8	9.5
20	20	4.25	35	11	3.2	6.6
21	21	4.25	31	9	3.0	9.7
22	22	4.20	34	11	2.6	5.6
23	23	4.40	25	9	2.4	1.4
24	24	4.40	23	8	2.3	10.0
25	25	4.35	24	9	2.1	1.0
26	26	4.45	23	4	1.9	1.0
27	27	4.40	23	8	1.9	1.0
28	28	4.45	23	8	1.8	1.0
29	29	4.50	21	6	1.6	13.4
30	30	4.55	20	5	1.6	10.6
31	31	4.50	19	6	1.4	9.6
32	32	4.55	20	6	1.4	3.4
33	33	4.50	17	5	1.3	6.6
34	34	4.50	18	5	1.3	1.5
35	35	4.50	20	5	1.2	1.8
36	36	4.55	17	5	1.2	2.0
37	37	4.50	18	5	1.1	1.0
38	38	4.55	16	6	1.2	1.0

TABLE XXV (Continued)

COLUMN NO. 8
PHASE I - METHANE
ANALYTICAL AND OTHER DATA

Day Of Operation				Hot Acid		
Project	Phase I	pH	Sp. Cond. mmhos	as $CaCO_3$	Iron as Fe	Sulfate as SO_4
39	39	4.55	16	5	1.1	1.0
40	40	4.55	15	4	1.1	1.6
41	41	4.60	15	4	1.0	8.7
42	42	4.60	14	4	1.0	1.0
43	43	4.60	14	5	0.8	1.0
44	44	4.70	14	4	0.8	1.0
45	45	4.65	14	4	0.8	4.3
46	46	4.55	14	5	0.8	1.0
47	47	4.50	15	5	0.7	1.0
48	48	4.25	22			
49	49	4.55	15	4	0.7	4.6
50	50	4.60	15	4	0.7	4.5
51	51	4.60	15	3	0.7	1.0
52	52	4.50	16	4	0.7	5.3
53	53	4.50	16	4	0.7	1.0
54	54	4.50	15	5	0.6	2.5
55	55	4.50	14	5	0.6	7.2
56	56	4.45	13	6	0.6	6.1
57	57	4.50	14	4	0.6	1.0
58	58	4.60	12	4	0.5	1.0
59	59	4.70	12	4	0.5	1.0
60	60	4.50	14	4	0.6	1.0
61	61	4.40	13	4	0.6	1.0
62	62	4.45	15	4	0.5	4.4
63	63	4.50	16	5	0.5	1.0
64	64	4.65	16	3	0.5	1.0
65	65	4.50	15	4	0.5	1.0
66	66	4.85	12	4	0.4	11.7
67	67	4.85	11	5	0.4	3.5
68	68	4.35	16	4	0.5	1.0
69	69	4.45	15	4	0.5	1.0
70	70	4.40	16	5	0.6	1.5
71	71	4.60	13	4	0.5	1.0
72	72	4.50	15	5	0.5	2.5
73	73	4.50	16	4	0.4	6.6
74	74	4.50	13			
75	75	4.45	14	5	0.5	6.5
76	76	4.50	13	5	0.4	1.0

TABLE XXV(Continued)

COLUMN NO. 8
PHASE I - METHANE
ANALYTICAL AND OTHER DATA

Day Of Operation Project	Day Of Operation Phase I	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
77	77	4.50	13	4	0.3	1.0
78	78	4.70	11	4	0.3	1.0
79	79	4.90	12	4	0.3	1.0
80	80	4.70	11			

TABLE XXVI

COLUMN NO. 9
PHASE I - CARBON DIOXIDE
ANALYTICAL AND OTHER DATA

Day Of Operation						
Project	Phase I	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
1	1	3.10	650	380	141.0	300.0
2	2	3.40	330	156	67.8	128.0
3	3	3.65	240	92	40.3	67.5
4	4	3.75	200	68	26.7	63.9
5	5	3.85	150	72	23.1	35.3
6	6	3.85	145	44	17.0	38.7
7	7	3.90	120	44	15.5	37.7
8	8	3.80	100	64	10.6	15.9
9	9	3.75	87	24	9.2	9.1
10	10	3.70	97	24	8.6	1.4
11	11	3.75	85	22	7.1	13.0
12	12	3.75	83	20	6.4	8.4
13	13	3.70	85	20	5.5	1.4
14	14	3.80	83	16	5.0	4.9
15	15	4.15	79	14	5.0	14.0
16	16	3.75	72	15	4.6	15.6
17	17	3.75	73	14	5.2	9.2
18	18	3.80	74	18	4.7	4.5
19	19	3.75	69	23	4.1	8.8
20	20	3.75	65	11	3.6	10.4
21	21	3.80	62	10	3.3	11.1
22	22	3.75	64	12	3.0	7.8
23	23	3.75	57	10	2.7	1.4
24	24	3.80	59	19	2.4	10.0
25	25	3.75	57	116	2.3	1.0
26	26	3.80	55	7	2.2	1.0
27	27	3.80	55	8	1.8	1.0
28	28	3.80	56	24	2.1	1.0
29	29	3.80	56	17	1.9	1.0
30	30	3.80	56	5	1.8	9.3
31	31	3.85	54	5	1.7	12.2
32	32	3.90	53	5	1.7	12.0
33	33	3.90	53	5	1.6	8.1
34	34	3.80	53	5	1.6	4.6
35	35	3.80	52	4	1.5	15.9
36	36	3.80	52	5	1.4	1.0
37	37	3.80	51	5	1.3	4.8
38	38	3.80	50	6	1.5	14.4

TABLE XXVI (Continued)

COLUMN NO. 9
PHASE I - CARBON DIOXIDE
ANALYTICAL AND OTHER DATA

Day Of Operation						
Project	Phase I	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
39	39	3.80	50	4	1.4	4.1
40	40	3.80	48	4	1.3	1.0
41	41	3.85	48	4	1.3	1.0
42	42	3.90	46	4	1.3	3.2
43	43	3.80	47	4	1.1	3.9
44	44	3.80	47	4	1.1	1.0
45	45	3.90	47	4	1.0	1.0
46	46	3.80	47	3	1.0	1.0
47	47	3.85	48	4	1.0	1.0
48	48	3.80	53			
49	49	3.90	48	3	0.9	4.5
50	50	3.90	49	4	1.0	3.5
51	51	3.95	50	3	1.0	2.2
52	52	3.90	48	4	1.0	4.5
53	53	3.90	46	4	0.8	5.4
54	54	3.90	46	5	0.9	1.0
55	55	3.90	46	5	0.8	6.6
56	56	3.90	45	6	0.7	9.0
57	57	3.90	45	3	0.8	1.0
58	58	3.85	43	3	1.2	1.0
59	59	3.90	47	4	1.3	1.0
60	60	3.90	49	5	0.9	1.0
61	61	3.90	50	4	0.9	1.0
62	62	3.85	50	4	0.8	1.0
63	63	3.90	50	4	0.7	1.0
64	64	3.50		4	0.7	1.0
65	65	3.90	53	3	0.7	1.0
66	66	4.00	52	3	0.7	1.0
67	67	4.00	51	3	0.7	7.2
68	68	4.05	52	3	0.7	3.3
69	69	4.00	53	3	0.6	5.2
70	70	4.00	48	4	0.7	1.0
71	71	4.00	47	4	0.7	1.0
72	72	3.95	46	4	0.7	4.5
73	73	3.95	48	5	0.7	6.7
74	74	4.00	46			
75	75	4.00	48	5	1.1	1.0
76	76	4.00	46	5	0.8	7.9

TABLE XXVI (Continued)

COLUMN NO. 9
PHASE I - CARBON DIOXIDE
ANALYTICAL AND OTHER DATA

Day Of Operation Project	Day Of Operation Phase I	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
77	77	4.00	45	4	0.8	1.2
78	78	4.05	4-	4	0.7	2.1
79	79	3.90	47	4	0.7	1.0
80	80	4.00	53	4	0.7	1.0
81	81	4.00	47	4	0.7	1.0
82	82	4.00	47	5	0.8	1.0
83	83	4.04	47	4	0.8	1.0

TABLE XXVII

COLUMN FEEDWATER
DAILY ANALYTICAL DATA

Day of Operation	pH	Specific Conductance mmhos	Hot Acid as $CaCO_3$	Dissolved Oxygen
1	5.80	1.0		
2	6.40	0.9		
3	6.10	1.4		0
4	6.50	0.9		
5	6.20	1.2		
6	6.35	1.7		0
7	6.70	1.3	6	0
8	6.50	1.1		0
9	6.40	1.2		0
10	6.20	1.9		
11	6.45	1.4		
12	6.75	1.3		
13	6.40	1.7		
14	6.40	1.2		0
15	5.75	1.3		0
16	5.75	0.8		
17	5.80	1.3		0
18	5.75	0.8		
19	6.05	1.0		
20	5.95	0.8		0
21	5.65	1.0		0
22	6.10	0.7		
23	5.85	1.0		
24	5.65	0.9		
25	6.00	0.9		
26	6.15	0.9		
27	6.20	0.9		0
28				0
29	6.20	1.1		0
30	6.00	0.7		
31	6.25	1.3		0
32	6.20	1.0		
33	6.15	1.0		
34	5.65	1.2		0
35	5.90	1.5		
36	5.60	1.0		
37	5.50	1.2		
38	5.90	1.2		0

TABLE XXVII (Continued)

COLUMN FEEDWATER
DAILY ANALYTICAL DATA

Day of Operation	pH	Specific Conductance mmhos	Hot Acid as $CaCO_3$	Dissolved Oxygen
39	6.00	1.1		
40	6.30	1.0		
41	6.50	1.1		0
42	6.35	1.2		
43	6.35	1.1		
44	5.70	0.9		0
45	6.00	1.0		
46	5.65	1.3		
47	5.60	2.5		
48	5.00	2.0		
49	5.50	1.2		
50	6.30	1.0		
51				
52				
53				
54				
55				
56	5.75	1.5		
57	5.80	0.9		0
58	5.80	1.0		
59				0
60	5.90	0.9		
61	5.55	1.4		
62	5.60	1.0		0
63	6.00	1.2		0
64	5.70	1.2		
65	6.00	1.2		
66	5.90	0.9		
67	6.25	1.5		
68	5.60	1.3		
69	5.50	1.0	3.5	
70	5.90	1.1		0
71	5.65	1.1		0
72	5.60	1.4		
73	5.40	1.5		
74	5.55	1.3		
75	5.25	2.5		
76	5.55	1.3		

TABLE XXVII (Continued)

COLUMN FEEDWATER
DAILY ANALYTICAL DATA

Day of Operation	pH	Specific Conductance mmhos	Hot Acid as $CaCO_3$	Dissolved Oxygen
77	5.40	0.9		
78	5.80	0.8		
79				
80	5.85	1.0		
81	5.85	1.0		
82	5.50	1.2		
83	5.60	1.4		0
84	5.80	1.2		
85	5.50	1.0		
86	5.50	1.1		
87	5.70	0.9		0
88	5.45	1.0		
89	5.40	1.2		
90	5.40	1.0		0
91	5.95	1.5		0
92	5.70	1.2	5.0	
93	5.80	1.3		
94	6.00	1.2		
95	5.80	1.3		
96	5.90	1.0		
97		1.1	2.0	0
98	5.80	1.2		
99	5.70	1.3		
100	6.00	1.3		
101	6.10	0.9		0
102	5.80	1.4		
103	5.85	1.3		
104	6.20	0.6	4.0	
105	5.75	2.0		
106	5.70	0.8	2.0	
107	6.60	0.5		
108	5.05	8.0		
109	5.95	9.0		
110		5.0		
111		5.0	2.0	0
112	5.65	5.0		
113	5.95	3.5		
114	6.05	4.0		0

TABLE XXVII (Continued)

COLUMN FEEDWATER
DAILY ANALYTICAL DATA

Day of Operation	pH	Specific Conductance mmhos	Hot Acid as $CaCO_3$	Dissolved Oxygen
115	6.05			
116				
117				
118			1.0	0
119	5.80	2.5		
120	6.05	3.5		
121	5.85	3.5		
122	6.05	3.0		
123	6.10	3.5		
124	6.00	3.0		
125	6.05	3.0	1.0	0
126	5.95	3.0		
127	5.75	3.5		
128	5.40	4.0		
129	5.55	2.5		
130	5.60	2.5		
131	5.60	2.5		
132	5.45	2.0	1.0	
133	5.85	2.5		0
134	5.65	3.5		
135				
136	5.75	2.5		1.2
137				1.2
138				
139				
140				
141	6.50	3.0		0
142	5.85	2.5		0
143				
144				
145				
146	5.75	3.0		0
147	5.75	3.0		0
148	5.70	3.0		0
149	5.70	3.0		0

TABLE XXVIII

COLUMN NO. 1
PHASE II - 99.5% NITROGEN + 0.5% OXYGEN
ANALYTICAL AND OTHER DATA

Day Of Operation				Hot Acid		
Project	Phase II	pH	Sp. Cond. mmhos	as $CaCO_3$	Iron as Fe	Sulfate as SO_4
81	1	4.95	13	6	1.1	1.0
82	2	4.75	17	7	1.7	1.0
83	3	4.55	24	8	2.1	1.0
84	4	4.45	28	10	2.2	1.0
85	5	4.40	31	9	2.3	1.0
86	6	4.15	37	11	2.3	7.1
87	7	4.15	39	10	2.2	1.0
88	8	4.05	42	11	2.3	7.8
89	9	4.15	41	11	2.0	13.2
90	10	4.10	45	11	2.3	17.1
91	11	3.95	46	12	2.3	11.8
92	12	4.40	48	13	2.4	11.7
93	13	3.80	53	15	2.5	8.2
94	14	4.20	44	11	2.2	5.5
95	15	4.20	40	11	2.1	17.5
96	16	4.40	48	12	2.5	12.0
97	17	4.10	52	13	2.3	16.9
98	18	4.00	48	12	2.1	15.4
99	19	4.35	52	11	2.5	1.0
100	20	4.55	50	11	2.1	8.8
101	21	4.60	51	12	2.6	2.4
102	22	4.20	50	12	2.0	13.0
103	23	4.30	51	12	2.3	12.0
104	24	4.10	60	12	2.4	12.0
105	25	4.20	60	13	2.6	19.8
106	26	4.15	57	13	2.5	12.6
107	27	4.10	54	12	2.4	19.0
108	28	4.00	63	13	2.6	18.5
109	29	3.90	83	17	3.6	14.8
110	30	3.90	67	16	3.5	11.6
111	31	3.85	68	16	6.5	14.2
112	32	4.10	56	14	3.2	4.3
113	33	4.05	48	16	2.9	5.6
114	34	4.10	46	18	2.8	11.6
115	35	4.00	63	14	2.9	17.6
116	36	4.00	55	16	2.6	1.0
117	37	4.05	60	14	2.5	6.0
118	38	4.00	55	15	2.6	7.8

TABLE XXVIII (Continued)

COLUMN NO. 1
PHASE II - 99.5% NITROGEN + 0.5% OXYGEN
ANALYTICAL AND OTHER DATA

Day Of Operation						
Project	Phase II	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
119	39	4.00	65	16	2.6	1.0
120	40	4.00	63	15	3.0	12.2
121	41	4.00	65	16	3.1	16.9
122	42	3.95	63	19	3.1	11.1
123	43	3.95	67	17	3.1	18.0
124	44	3.95	65	16	2.9	19.3
125	45	4.00	67	15	3.0	29.7
126	46	4.00	65	15	2.9	13.0
127	47	4.00	67	17	2.9	5.2
128	48	3.80	72	12	3.0	9.7
129	49	3.95	72	16	3.1	5.0
130	50	3.95	85	15	3.2	13.0
131	51	3.95	77	17	3.0	14.2
132	52	3.90	70	19	3.0	22.3
133	53	4.00	70	14	3.1	12.7
134	54	3.95	74	15	3.1	8.9
135	55					
136	56	4.00	74	19	3.0	12.0
137	57	3.95	80	17	3.4	10.5
138	58					
139	59	4.00	80	18	3.3	14.6
140	60	3.70	82	15	3.2	6.2
141	61	3.95	75	17	3.2	6.2
142	62	3.95	76	17	3.0	12.5
143	63					
144	64					
145	65					
146	66	3.90	75	16	3.0	11.9
147	67	3.95	78	16	3.3	12.3
148	68	3.95	75	17	3.2	13.9
149	69	3.65	95	24	4.3	28.3

TABLE XXIX

COLUMN NO. 2
PHASE II - NITROGEN GAS
(AIR SATURATED WATER)
ANALYTICAL AND OTHER DATA

Day of Operation Project	Day of Operation Phase II	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
85	1	5.05	10	4	0.6	1.0
86	2	4.80	11	5	0.7	1.0
87	3	4.80	12	4	0.8	8.2
88	4	4.50	14	5	0.9	1.0
89	5	4.65	14	5	0.9	1.0
90	6	4.65	15	6	0.9	1.0
91	7	4.40	18	6	0.8	8.3
92	8	4.70	18	5	0.9	1.0
93	9	4.20	18	8	1.0	1.2
94	10	4.50	17	6	0.9	1.0
95	11	4.75	16	6	0.8	11.8
96	12	4.80	18	6	0.9	19.0
97	13	4.50	20	5	0.9	5.6
98	14	4.50	16	6	0.8	10.8
99	15	4.35	20	7	0.9	6.1
100	16	4.75	20	6	0.7	6.4
101	17	4.55	20	4	0.8	1.0
102	18	4.55	20	6	0.8	4.0
103	19	4.60	20	7	0.7	12.0
104	20	4.50	23	5	0.7	18.0
105	21	4.50	23	5	0.6	29.0
106	22	4.50	22	7	0.8	7.0
107	23	4.50	22	7	0.7	13.0
108	24	4.30	26	5	0.7	6.7
109	25	4.65	30	7	1.1	1.0
110	26	4.40	23	6	1.0	5.2
111	27	4.40	26	6	0.9	1.0
112	28		21	5	0.8	1.0
113	29	4.45	20	8	0.8	1.0
114	30	4.50	19	8	0.7	6.6
115	31	4.40	21	5	0.7	1.0
116	32	4.45	18	19	0.6	1.0
117	33	4.45	20	5	0.6	2.8
118	34	4.45	19	7	0.7	1.0
119	35	4.55	22	5	0.7	6.1
120	36	4.50	21	5	0.8	6.7
121	37	4.50	23	5	0.8	14.8
122	38	4.45	23	6	0.8	1.0

TABLE XXIX (Continued)

COLUMN NO. 2
PHASE II - NITROGEN GAS
(AIR SATURATED WATER)
ANALYTICAL AND OTHER DATA

Day of Operation Project	Day of Operation Phase II	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
123	39	4.45	24	5	0.8	15.0
124	40	4.45	23	7	0.7	28.7
125	41	4.35	23	5	0.7	21.0
126	42	4.45	23	5	0.8	5.3
127	43	4.35	24	6	0.8	1.4
128	44	4.15	28	5	0.9	1.0
129	45	4.35	27	7	1.0	1.0
130	46	4.30	25	7	1.0	1.5
131	47	4.30	27	7	1.0	3.7
132	48	4.30	26	8	1.0	16.3
133	49	4.40	27	7	1.0	4.6
134	50	4.35	30	6	1.1	13.1
135	51					
136	52	3.95	33	8	0.9	1.2
137	53	4.30	28	7	0.8	1.0
138	54					
139	55	4.45	30	8	1.2	1.0
140	56	3.90	31	5	1.2	3.4
141	57	4.40	30	6	1.3	4.4
142	58	4.30	35	8	1.2	1.0
143	59					
144	60					
145	61					
146	62	4.20	40	9	1.3	11.6
147	63	4.30	45	10	1.5	6.5
148	64	4.15	45	11	1.8	7.7
149	65	3.85	55	14	2.4	18.7

TABLE XXX

COLUMN NO. 4
PHASE II - NITROGEN
ANALYTICAL AND OTHER DATA

Day Of Operation						
Project	Phase II	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
78	1	3.65	200	62	18.0	51.0
79	2	3.95	130	40	11.0	23.9
80	3	4.10	80	28	7.6	13.6
81	4	4.15	51	28	6.1	9.0
82	5	4.25	43	18	5.3	4.9
83	6	4.30	39	16	4.6	7.8
84	7	4.30	37	13	3.9	2.8
85	8	4.40	30	12	3.4	1.0
86	9	4.40	28	10	3.0	1.0
87	10	4.40	27	11	2.6	1.0
88	11	4.40	25	10	2.4	9.8
89	12	4.45	23	9	2.4	8.9
90	13	4.60	24	9	1.8	1.6
91	14	4.40	24	9	1.9	11.6
92	15	4.40	23	9	1.6	7.7
93	16	4.20	23	10	2.3	14.7
94	17	4.45	18	8	1.5	3.6
95	18	4.70	17	7	1.3	9.2
96	19	4.80	17	7	1.4	16.8
97	20	4.40	18	6	1.3	4.7
98	21	4.35	16	3	1.2	3.2
99	22	4.70	17	5	1.1	7.5
100	23	4.80	16	5	0.9	9.1
101	24	4.75	15	6	1.1	1.0
102	25	4.80	15	7	1.0	7.0
103	26	4.75	14	4	1.0	1.0
104	27	4.70	16	4	0.9	13.0
105	28	4.75	15	4	0.9	12.3
106	29	4.70	13	4	0.9	13.3
107	30	4.70	14	5	0.8	3.9
108	31	4.55	19	4	0.7	3.3
109	32	4.55	19	6	1.1	1.0
110	33	4.70	15	5	1.0	1.0
111	34	4.65	16	5	1.0	3.6
112	35	4.80	14	4	0.9	1.0
113	36	4.80	11	6	0.7	1.0
114	37	4.80	11	6	0.7	9.8
115	38	4.80	14	4	0.7	1.0

TABLE XXX(Continued)

COLUMN NO. 4
PHASE II - NITROGEN
ANALYTICAL AND OTHER DATA

Day of Operation						
Project	Phase II	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
116	39	4.80	10	11	0.5	1.0
117	40	4.85	15	4	0.6	1.0
118	41	4.80	10	2	0.6	1.0
119	42	4.80	11	2	0.5	11.1
120	43	4.80	11	4	0.5	4.7
121	44	4.80	11	6	0.6	11.9
122	45	4.85	11	5	0.6	5.1
123	46	4.85	11	4	0.5	6.2
124	47	4.85	10	5	0.5	9.6
125	48	4.70	10	3	0.5	9.1
126	49	4.85	10	4	0.5	5.9
127	50	4.80	11	5	0.5	1.0
128	51	4.70	13	4	0.5	4.2
129	52	4.75	12	4	0.5	1.0
130	53	4.75	10	5	0.5	4.1
131	54	4.75	11	5	0.4	12.1
132	55	4.75	10	4	0.7	6.9
133	56	4.75	13	7	0.7	11.0
134	57	4.70	15	6	0.8	15.8
135	58					
136	59	4.80	15	7	0.8	5.2
137	60	4.75	15	6	0.8	4.3
138	61					
139	62	4.60	20	7	0.9	2.0
140	63	4.45	12	5	0.6	1.0
141	64	4.75	13	6	0.6	3.0
142	65	4.75	13	4	0.4	1.0
143	66					
144	67					
145	68					
146	69	4.85	10	4	0.3	5.0
147	70	4.80	11	4	0.4	4.6
148	71	4.80	10	3	0.4	3.0
149	72	4.65	13	5	0.5	5.2

TABLE XXXI

COLUMN NO. 5
PHASE II - METHANE
ANALYTICAL AND OTHER DATA

Day Of Operation						
Project	Phase II	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
81	1	3.55	230	72	24.0	54.5
82	2	3.90	115	42	14.0	18.5
83	3	4.10	70	32	9.1	5.2
84	4	4.20	56	20	7.2	6.3
85	5	4.30	44	16	5.8	10.7
86	6	4.30	37	14	4.8	1.2
87	7	4.40	36	22	4.1	1.0
88	8	4.30	30	12	3.4	10.8
89	9	4.30	28	11	2.7	12.0
90	10	4.50	26	10	2.4	3.0
91	11	4.40	25	9	2.5	4.8
92	12	4.40	25	9	2.0	12.4
93	13	4.20	23	10	2.2	5.7
94	14	4.30	18	8	1.8	3.4
95	15	4.75	14	6	1.5	10.6
96	16	4.80	17	8	1.6	24.2
97	17	4.40	17	7	1.3	5.9
98	18	4.40	16	5	1.3	6.1
99	19	4.75	16	7	1.3	24.3
100	20	4.80	15	5	1.3	1.0
101	21	4.75	15	6	1.3	1.0
102	22	4.80	14	5	1.2	4.0
103	23	4.75	13	6	1.0	9.0
104	24	4.70	16	5	1.0	9.0
105	25	4.74	15	4	1.0	12.6
106	26	4.70	13	5	0.8	8.4
107	27	4.80	13	4	0.9	2.8
108	28	4.50	17	5	0.8	12.0
109	29	4.60	15	5	1.0	1.8
110	30	4.50	18	4	1.1	1.0
111	31	4.70	15	5	1.0	1.0
112	32	4.90	13	5	0.9	1.0
113	33	4.80	10	6	0.8	1.0
114	34	4.80	10	3	0.8	1.0
115	35	4.80	14	4	0.7	10.0
116	36	4.80	10	10	0.7	3.1
117	37	4.80	14	4	0.6	1.0
118	38	4.80	9	3	0.6	12.0

TABLE XXXI (Continued)

COLUMN NO. 5
PHASE II - METHANE
ANALYTICAL AND OTHER DATA

Day Of Operation						
Project	Phase II	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
119	39	4.80	11	3	0.6	2.0
120	40	4.80	10	2	0.6	11.5
121	41	4.80	10	7	0.6	12.1
122	42	4.90	10	4	0.6	3.4
123	43	4.90	10	5	0.6	1.0
124	44	4.85	9	3	0.5	4.4
125	45	4.70	11	4	0.5	9.1
126	46	4.90	10	4	0.5	16.3
127	47	4.85	10	4	0.5	1.0
128	48	4.70	12	7	0.5	1.0
129	49	4.75	11	4	0.5	1.0
130	50	4.80	9	4	0.5	6.0
131	51	4.80	11	4	0.5	1.0
132	52	4.85	9	5	0.5	8.6
133	53	4.85	11	7	0.5	10.6
134	54	4.75	14	5	0.6	4.7
135	55					
136	56	4.80	10	5	0.6	1.0
137	57	4.80	10	5	0.6	3.6
138	58					
139	59	4.70	14	4	0.8	1.2
140	60	4.60	10	3	0.8	1.0
141	61	4.75	14	5	0.7	1.0
142	62	4.75	12	4	0.5	1.0
143	63					
144	64					
145	65					
146	66	4.85	10	4	0.4	2.0
147	67	4.80	12	4	0.4	4.8
148	68	4.80	10	4	0.4	2.9
149	69	4.80	12	5	0.6	3.5

TABLE XXXII

COLUMN NO. 7
PHASE II - NITROGEN GAS
(NORMAL WATER FLOW RATE)
ANALYTICAL AND OTHER DATA

Day of Operation				Hot Acid		
Project	Phase II	pH	Sp. Cond. mmhos	as $CaCO_3$	Iron as Fe	Sulfate as SO_4
106	1	3.40	311	144	26.0	99.0
107	2	3.40	115	48	12.0	43.0
108	3	3.80	109	32	8.9	18.7
109	4	4.05	88	28	8.2	18.3
110	5	4.10	64	22	7.4	12.4
111	6	4.10	68	17	5.4	17.9
112	7	4.25	57	13	4.6	1.0
113	8	4.25	44	14	3.9	5.1
114	9	4.20	38	11	3.3	7.9
115	10	4.40	29	9	3.4	13.0
116	11	4.45	31	15	2.6	1.0
117	12	4.40	22	9	2.4	1.0
118	13	4.45	29	8	2.1	17.2
119	14	4.60	22	6	2.0	7.3
120	15	4.50	26	7	1.7	0.6
121	16	4.50	28	9	1.7	2.2
122	17	4.45	26	6	1.6	6.2
123	18	4.45	25	8	1.5	2.6
124	19	4.45	25	7	1.4	8.5
125	20	4.25	24	6	1.3	1.3
126	21	4.45	24	6	1.2	4.2
127	22	4.60	24	9	1.2	1.0
128	23	4.55	24	9	1.1	1.0
129	24	4.60	17	8	0.8	
130	25	4.60	15	8	1.2	1.0
131	26	4.65	17	6	0.9	6.4
132	27	4.60	15	9	0.9	11.5
133	28	4.60	16	10	1.1	5.4

TABLE XXXIII

COLUMN NO. 7
PHASE II - NITROGEN GAS
(REDUCED WATER FLOW RATE)
ANALYTICAL AND OTHER DATA

Day Of Operation		pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
Project	Phase II					
134	1	4.20	50	16	4.1	17.7
135	2					
136	3		60	18	4.6	21.8
137	4	4.20	61	20	4.2	10.7
138	5					
139	6	4.20	63	21	6.0	18.4
140	7	3.80	64	17	5.5	6.5
141	8	4.25	60	16	5.4	11.3
142	9	4.15	53	20	3.9	10.9
143	10					
144	11					
145	12					
146	13	4.15	49	14	3.4	12.4
147	14	4.20	50	15	3.3	12.1
148	15	4.20	53	15	3.3	11.2
149	16	4.00	55	16	3.5	20.2

TABLE XXXIV

COLUMN NO. 8
PHASE II - METHANE + 0.1% OXYGEN
ANALYTICAL AND OTHER DATA

Day Of Operation						
Project	Phase II	pH	Sp. Cond. mmhos	Hot Acid as CaCO3	Iron as Fe	Sulfate as SO4
81	1	4.65	12	4	0.6	1.0
82	2	4.60	13	5	0.7	1.0
83	3	4.60	14	5	0.8	1.0
84	4	4.65	17	5	0.8	1.0
85	5	4.50	15	5	0.8	1.0
86	6	4.60	17	7	0.9	1.0
87	7	4.45	17	6	0.8	1.0
88	8	4.40	18	7	0.9	2.3
89	9	4.30	20	6	0.8	9.4
90	10	4.45	20	6	0.7	1.0
91	11	4.35	21	7	0.8	10.8
92	12	4.35	25	7	0.8	5.6
93	13	4.10	24	6	0.9	6.4
94	14	4.60	18	5	0.8	14.0
95	15	4.55	18	6	0.7	1.0
96	16	4.55	20	8	0.9	10.8
97	17	4.25	22	5	0.7	9.3
98	18	4.40	22	6	0.7	17.8
99	19	4.20	22	5	0.7	11.1
100	20	4.55	22	7	0.7	9.5
101	21	4.45	22	7	0.6	35.0
102	22	4.40	22	6	0.7	4.0
103	23	4.50	22	6	0.7	25.0
104	24	4.50	23	5	0.8	20.0
105	25	4.40	25	5	0.8	14.0
106	26	4.35	26	5	0.6	9.1
107	27	4.40	22	5	0.6	6.5
108	28	4.40	29	4	0.7	1.0
109	29	4.30	33	6	1.0	1.0
110	30	4.35	29	7	1.0	6.1
111	31	4.30	32	6	0.9	9.4
112	32	4.40	24	6	0.8	3.2
113	33	4.35	25	8	0.8	1.0
114	34	4.50	24	5	0.8	4.9
115	35	4.50	18	6	0.8	9.2
116	36	4.45	25	5	0.7	2.6
117	37	4.45	19	15	0.7	16.7
118	38	4.45	23	6	0.7	1.0

TABLE XXXIV (Continued)

COLUMN NO. 8
PHASE II - METHANE + 0.1% OXYGEN
ANALYTICAL AND OTHER DATA

Day Of Operation						
Project	Phase II	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
119	39	4.55	20	6	0.7	13.7
120	40	4.45	24	8	0.7	1.0
121	41	4.45	25	6	0.7	6.9
122	42	4.40	25	5	0.8	6.1
123	43	4.45	24	7	0.7	7.2
124	44	4.40	25	5	0.7	8.7
125	45	4.20	25	5	0.7	35.7
126	46	4.35	27	5	0.6	5.3
127	47	4.30	27	5	0.7	1.0
128	48	4.35	28	9	0.7	1.0
129	49	4.30	23	8	0.3	1.0
130	50	4.35	23	7	0.8	1.0
131	51	4.30	25	8	0.7	11.6
132	52	4.30	23	8	0.7	7.1
133	53	4.40	22	10	0.8	3.7
134	54	4.40	23	7	0.8	8.9
135	55					
136	56	4.35	26	5	0.7	1.0
137	57	4.35	25	6	0.8	3.0
138	58					
139	59	4.20	29	9	1.1	5.3
140	60	4.30	23	7	1.1	1.0
141	61	4.35	26	7	1.0	1.0
142	62	4.30	35	11	1.7	7.6
143	63					
144	64					
145	65					
146	66	4.10	52	12	2.2	17.1
147	67	4.15	49	12	2.3	11.2
148	68	4.15	55	13	2.5	7.7
149	69	3.90	71	18	3.6	22.8

TABLE XXXV

COLUMN NO. 9
PHASE II - 99% CARBON DIOXIDE + 1% OXYGEN
ANALYTICAL AND OTHER DATA

Day Of Operation Project	Day Of Operation Phase II	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
84	1	3.90	73	10	1.8	1.0
85	2	3.80	110	17	3.4	9.9
86	3	3.65	120	19	1.6	10.5
87	4	3.65	125	19	4.4	1.0
88	5	3.65	125	25	5.0	19.3
89	6	3.70	125	21	5.0	18.5
90	7	3.65	130	22	5.0	18.5
91	8	3.60	140	30	5.1	22.1
92	9	3.60	145	27	5.4	18.5
93	10	3.55	140	25	6.2	18.5
94	11	3.90	120	22	5.8	19.2
95	12	3.90	120	24	5.8	22.0
96	13	3.85	125	23	6.6	36.1
97	14	3.65	135	22	5.8	20.1
98	15	3.70	125	23	6.3	11.4
99	16	3.85	130	23	5.7	19.0
100	17	3.85	135	23	5.8	20.7
101	18	3.80	125	30	7.1	9.8
102	19	3.80	130	30	6.0	26.0
103	20	3.80	125	26	6.8	13.4
104	21	3.80	125	23	6.5	21.0
105	22	3.80	125	24	6.6	9.4
106	23	3.70	110	22	5.9	39.0
107	24	3.80	115	24	5.8	14.2
108	25	3.80	130	22	5.8	1.0
109	26	3.85	88	20	6.2	15.0
110	27	3.75	130	42	25.0	26.8
111	28	3.60	165	49	16.0	42.9
112	29	3.70	180	42	14.0	26.0
113	30	3.70	125	31	9.0	
114	31	3.65	120	24	8.7	22.5
115	32	3.85	105	24	7.8	22.0
116	33	3.80	115	32	8.0	10.1
117	34	3.80	110	22	9.0	7.1
118	35	3.80	114	25	7.4	10.4
119	36	3.90	110	26	7.7	30.5
120	37	3.80	120	31	7.9	19.6
121	38	3.80	120	23	7.9	24.0

TABLE XXXV (Continued)

COLUMN NO. 9
PHASE II - 99% CARBON DIOXIDE + 1% OXYGEN
ANALYTICAL AND OTHER DATA

Day Of Operation Project	Day Of Operation Phase II	pH	Sp. Cond. mmhos	Hot Acid as $CaCO_3$	Iron as Fe	Sulfate as SO_4
122	39	3.75	120	22	8.2	33.2
123	40	3.75	120	27	7.7	2.5
124	41	3.80	125	24	7.5	10.7
125	42	3.70	125	22	7.4	14.9
126	43	3.70	125	24	7.2	20.3
127	44	3.65	130	22	7.6	15.2
128	45	3.70	135	27	7.3	18.8
129	46	3.65	125	24	3.0	21.5
130	47	3.70	130	23	7.8	21.2
131	48	3.65	125	29	7.7	16.5
132	49	3.60	125	28	7.6	27.8
133	50	3.70	125	32	7.7	20.1
134	51	3.80	130	24	7.8	20.5
135	52					
136	53	3.70	125	31	8.0	31.7
137	54	3.70	130	27	8.1	18.4
138	55					
139	56	5.10	138	31	8.6	23.1
140	57	3.60	130	32	8.3	28.9
141	58	3.80	130	29	8.8	14.2
142	59	3.65	125	56	8.2	20.1
143	60					
144	61					
145	62					
146	63	3.70	125	29	8.4	20.6
147	64	3.70	125	29	8.5	23.1
148	65	3.70	125	28	8.3	21.3
149	66	3.50	150	41	11.1	47.2

TABLE XXXVI

COLUMN NO. 2
PHASE II - NITROGEN GAS
(AIR SATURATED WATER)
FEEDWATER & EFFLUENT WATER
DISSOLVED OXYGEN DATA

Day Of Operation		Water Temp. °C	Dissolved Oxygen mg/l	
Project	Phase II		In	Out
85	1	14	6.4	
86	2	14		
87	3	14	8.4	4.4
88	4	14	8.4	5.6
89	5	14	8.4	2.6
90	6	14	8.2	3.2
91	7	14	7.8	2.4
92	8	15	8.2	1.8
93	9	14		
94	10	12	8.6	2.8
95	11	12	8.6	2.8
96	12	14	8.6	3.5
97	13	13	8.4	2.8
98	14	14	8.5	3.4
99	15	15	8.8	3.2
100	16	14	8.6	2.4
101	17	14	8.0	2.6
102	18	14	7.6	2.2
103	19	14	8.2	3.4
104	20	15	8.0	3.2
105	21	14	7.6	4.8
106	22	13	8.4	5.8
107	23	13	8.4	2.8
108	24	14		
109	25	14		
110	26	14		
111	27	14	8.5	3.2
112	28	14	8.2	3.0
113	29	13	8.4	2.8
114	30	12	8.6	3.0
115	31	12		
116	32	13		
117	33	13		
118	34	13		
119	35	13	8.5	3.0
120	36	14	8.5	2.9
121	37	14	8.3	3.0

TABLE XXXVI (Continued)

COLUMN NO. 2
PHASE II - NITROGEN GAS
(AIR SATURATED WATER)
FEEDWATER DISSOLVED OXYGEN DATA

Day Of Operation		Water Temp. °C	Dissolved Oxygen mg/l	
Project	Phase II		In	Out
122	38	14	8.4	2.8
123	39	14	8.3	3.0
124	40	14	8.4	2.9
125	41	13	8.3	2.8
126	42	13	8.5	2.9
127	43	13	8.6	3.0
128	44	13	8.5	2.7
129	45	14	8.2	2.7
130	46	13	7.9	3.0
131	47	14		
132	48	14	8.3	3.0
133	49	13	8.2	3.0
134	50	13	8.1	3.1
135	51			
136	52	14	8.5	2.9
137	53	13	8.6	3.0
138	54			
139	55			
140	56	14		2.8
141	57	14	8.5	2.9
142	58	14	8.5	2.9
143	59			
144	60			
145	61			
146	62	14	8.4	2.9
147	63	14	8.3	2.7
148	64	14	8.4	2.8
149	65	14	8.3	3.1

TABLE XXXVII

COLUMN NO. 1
WEEKLY SAMPLE DATA
MINOR CONSTITUENTS

Day Of Operation	Al	Mn	Mg	Ca	Fe^{++}
49	0.18	0.02	0.34	0.33	0.6
56	0.04	0.02	0.22	0.30	0.5
62	0.02	0.02	0.03	0.30	0.4
69	0.02	0.02	0.03	0.33	0.3
83	0.07	0.03	0.07	0.88	2.1
90	0.07	0.02	0.04	0.39	2.1
97	0.18	0.02	0.02	0.30	2.0
104	0.40	0.03	0.04	0.32	1.7
111	0.16	0.04	0.05	0.82	5.9
118	0.08	0.05	0.06	0.66	2.6
125	0.14	0.01	0.09	0.82	2.8
132	0.06	0.01	0.01	0.16	3.0

TABLE XXXVIII

COLUMN NO. 2
WEEKLY SAMPLE DATA
MINOR CONSTITUENTS

Day Of Operation	Al	Mn	Mg	Ca	Fe^{++}
49	0.15	0.02	0.41	0.34	0.6
56	0.04	0.02	0.22	0.30	0.5
62	0.14	0.02	0.03	0.30	0.5
69	0.02	0.02	0.05	0.60	0.4
83	0.05	0.05	0.05	0.36	
90	0.05	0.02	0.05	0.44	
97	0.16	0.02	0.02	0.28	
104	0.36	0.03	0.04	0.34	
111	0.14	0.04	0.03	0.44	
118	0.16	0.05	0.03	0.44	
125	0.05	0.02	0.02	0.27	
132	0.11	0.01	0.01	0.16	

TABLE XXXIX

COLUMN NO. 3
WEEKLY SAMPLE DATA
MINOR CONSTITUENTS

Day of Operation	Al	Mn	Mg	Ca	Fe++
49	0.11	0.02	0.43	0.37	0.6
56	0.25	0.02	0.27	0.35	0.5
62	0.12	0.02	0.02	0.30	0.5
69	0.02	0.02	0.03	0.38	0.4
83	0.05	0.04	0.05	0.39	0.3
90	0.06	0.03	0.04	0.30	0.2
97	0.15	0.02	0.02	0.21	0.3
104	0.15	0.02	0.03	0.20	0.2
111	0.17	0.02	0.02	0.22	0.3
118	0.05	0.05	0.10	1.20	0.2
125	0.05	0.01	0.03	0.38	0.2
132	0.02	0.01	0.01	0.13	0.2

TABLE XL

COLUMN NO. 4
WEEKLY SAMPLE DATA
MINOR CONSTITUENTS

Day Of Operation	Al	Mn	Mg	Ca	Fe^{++}
49	0.39	0.04	0.34	0.81	61.9
56	0.34	0.04	0.31	0.73	83.0
62	0.16	0.02	0.08	0.80	69.0
69	0.16	0.05	0.09	0.80	70.0
83	0.05	0.04	0.04	0.44	4.4
90	0.05	0.02	0.05	0.27	1.8
97	0.24	0.02	0.02	0.16	1.2
104	0.30	0.02	0.04	0.29	0.2
111	0.09	0.03	0.02	0.21	0.9
118	0.05	0.05	0.02	0.33	0.5
125	0.05	0.01	0.02	0.20	0.5
132	0.02	0.01	0.01	0.11	0.4

TABLE XLI

COLUMN NO. 5
WEEKLY SAMPLE DATA
MINOR CONSTITUENTS

Day Of Operation	Al	Mn	Mg	Ca	Fe^{++}
49	0.11	0.04	0.31	0.51	57.9
56	0.16	0.04	0.41	0.38	58.0
62	0.24	0.02	0.04	0.04	64.0
69	0.08	0.06	0.08	0.60	63.0
83	0.13	0.04	0.03	0.25	8.9
90	0.15	0.03	0.03	0.21	2.1
97	0.10	0.02	0.02	0.10	1.3
104	0.05	0.02	0.03	0.36	0.4
111	0.09	0.02	0.04	0.60	1.0
118	0.08	0.05	0.06	0.77	0.6
125	0.11	0.01	0.02	0.20	0.5
132	0.02	0.01	0.01	0.11	0.5

TABLE XLII

COLUMN NO. 6
WEEKLY SAMPLE DATA
MINOR CONSTITUENTS

Day Of Operation	Al	Mn	Mg	Ca	Fe^{++}
49	0.07	0.05	0.41	0.69	62.2
56	0.36	0.06	0.48	0.73	61.0
62	0.20	0.03	0.10	1.00	67.0
69	0.08	0.06	0.11	0.77	63.0
83	0.21	0.07	0.13	0.68	60.0
90	0.18	0.06	0.09	0.54	54.0
97	0.45	0.04	0.07	0.41	58.0
104	0.69	0.09	0.08	0.43	40.0
111	0.29	0.05	0.08	0.43	53.0
118	0.20	0.06	0.14	1.30	54.0
125	0.16	0.01	0.07	0.40	55.0
132	0.02	0.02	0.05	0.66	55.0

TABLE XLIII

COLUMN NO. 7
WEEKLY SAMPLE DATA
MINOR CONSTITUENTS

Day Of Operation	Al	Mn	Mg	Ca	Fe^{++}
49	0.05	0.03	0.31	0.51	58.0
56	0.11	0.14	3.20	2.80	250.0
62	0.30	0.14	0.18	1.30	235.0
69	0.42	0.15	0.21	1.60	212.0
83	0.28	0.04	0.05	0.54	61.0
90	0.13	0.04	0.06	0.34	50.0
97	0.29	0.04	0.02	0.46	53.0
104	0.64	0.13	0.05	0.26	45.0
111	0.12	0.02	0.02	0.19	5.2
118	0.05	0.05	0.01	0.55	2.1
125	0.05	0.01	0.01	0.16	1.3
132	0.02	0.01	0.01	0.12	0.9

TABLE XLIV

COLUMN NO. 8
WEEKLY SAMPLE DATA
MINOR CONSTITUENTS

Day Of Operation	Al	Mn	Mg	Ca	Fe^{++}
49	0.04	0.02	0.33	0.43	0.7
56	0.15	0.02	0.22	0.32	0.5
62	0.04	0.02	0.06	0.40	0.5
69	0.02	0.03	0.02	0.38	0.4
83	0.05	0.03	0.03	0.45	0.8
90	0.05	0.02	0.05	0.35	0.7
97	0.15	0.02	0.02	0.23	0.7
104	0.10	0.02	0.03	0.46	0.7
111	0.12	0.03	0.05	0.55	0.9
118	0.10	0.05	0.02	0.33	0.7
125	0.08	0.01	0.03	0.36	0.7
132	0.04	0.01	0.01	0.14	0.7

TABLE XLV

COLUMN NO. 9
WEEKLY SAMPLE DATA
MINOR CONSTITUENTS

Day Of Operation	Al	Mn	Mg	Ca	Fe^{++}
49	0.18	0.02	0.33	0.58	0.9
56	0.30	0.02	0.24	0.50	0.7
62	0.23	0.02	0.03	0.50	0.8
69	0.03	0.03	0.05	0.60	0.6
83	0.05	0.02	0.07	0.61	0.6
90	0.05	0.02	0.05	0.49	5.0
97	0.35	0.02	0.03	0.37	5.8
104	0.32	0.08	0.05	0.27	5.4
111	0.37	0.02	0.01	0.22	15.0
118	0.06	0.05	0.02	0.44	7.4
125	0.08	0.01	0.05	0.50	6.8
132	0.02	0.01	0.01	0.22	7.6

TABLE XLVI

COLUMN NO. 1 - PHASE II
NITROGEN + 0.523% OXYGEN
INLET AND OUTLET GAS ANALYSES

Day Of Operation		% Oxygen In Inlet Gas	% Oxygen In Outlet Gas	Difference	Gas Flow Rate
Project	Phase II				
125	45	0.523	0.500	0.023	45 cc/min
127	47	0.523	0.500	0.023	45 cc/min
128	48	0.523	0.440	0.083	45 cc/min
129	49	0.523	0.440	0.083	45 cc/min
132	52	0.523	0.469	0.054	45 cc/min
133	53	0.523	0.483	0.040	45 cc/min
134	54	0.523	0.479	0.044	45 cc/min
136	56	0.523	0.436	0.087	45 cc/min
137	57	0.523	0.361	0.162	45 cc/min
141	61	0.523	0.384	0.139	45 cc/min
142	62	0.523	0.418	0.105	45 cc/min
146	66	0.523	0.436	0.087	45 cc/min
147	67	0.523	0.441	0.082	45 cc/min
148	68	0.523	0.390	0.133	45 cc/min
149	69	0.523	0.392	0.131	45 cc/min
*142	62	0.523	0.418	0.105	45 cc/min
146	66	0.523	0.447	0.076	45 cc/min
147	67	0.523	0.441	0.082	45 cc/min
148	68	0.523	0.397	0.126	45 cc/min
149	69	0.523	0.403	0.120	45 cc/min

*The column operating on a methane-oxygen mixture (Column No. 8) was changed to nitrogen + 0.523% oxygen on 12/2/70.

TABLE XLVII

COLUMN NO. 8 - PHASE II
METHANE + 0.11% OXYGEN
INLET AND OUTLET GAS ANALYSES

Day Of Operation		% Oxygen In Inlet Gas	% Oxygen In Outlet Gas	Difference	Gas Flow Rate
Project	Phase II				
125	45	0.112	0.087	0.025	30 cc/min
133	53	0.112	0.098	0.014	30 cc/min
134	54	0.112	0.077	0.035	30 cc/min
136	56	0.112	0.092	0.020	30 cc/min
137	57	0.112	0.066	0.046	30 cc/min
141	61	0.112	0.060	0.052	30 cc/min

TABLE XLVIII

COLUMN NO. 9 - PHASE II
CARBON DIOXIDE + 1.07% OXYGEN
INLET AND OUTLET GAS ANALYSES

Day Of Operation		% Oxygen In Inlet Gas	% Oxygen In Outlet Gas	Difference	Gas Flow Rate
Project	Phase II				
121	38	1.07	0.390	0.680	45 cc/min
125	42	1.07	0.514	0.556	45 cc/min
127	44	1.07	0.871	0.199	45 cc/min
128	45	1.07	0.924	0.146	45 cc/min
134	51	1.07	0.659	0.411	45 cc/min
136	53	1.07	0.993	0.077	45 cc/min
137	54	1.07	0.963	0.107	45 cc/min
141	58	1.07	0.856	0.214	45 cc/min
146	63	1.07	0.781	0.289	45 cc/min
147	64	1.07	0.996	0.074	45 cc/min
149	66	1.07	0.927	0.143	45 cc/min

TABLE XLIX

COLUMN NO. 6 - AIR CONTROL
NITROGEN + 20.9% OXYGEN

Day of Operation	% Oxygen In Inlet Gas	% Oxygen In Outlet Gas	Difference	Gas Flow Rate
1	20.9	19.8	1.1	10 cc/min
2	20.9	19.8	1.1	86 cc/min
3	20.9	19.9	0.9	86 cc/min
4	20.9	20.4	0.5	86 cc/min
5	20.9	20.4	0.5	86 cc/min
6	20.9	20.4	0.5	86 cc/min
7	20.9	20.4	0.5	86 cc/min
8	20.9	20.4	0.5	86 cc/min
44	20.9	19.6	1.3	45 cc/min
121	20.9	19.2	1.7	45 cc/min
125	20.9	19.5	1.4	45 cc/min
127	20.9	18.1	2.8	45 cc/min
129	20.9	19.2	1.7	45 cc/min
132	20.9	18.4	2.5	45 cc/min
133	20.9	19.3	1.6	45 cc/min
134	20.9	18.4	2.5	45 cc/min
137	20.9	18.9	2.0	45 cc/min
141	20.9	17.5	3.4	45 cc/min
142	20.9	17.3	3.6	45 cc/min
146	20.9	17.0	3.9	45 cc/min
147	20.9	18.7	2.2	45 cc/min
148	20.9	19.6	1.3	45 cc/min

BIBLIOGRAPHIC:

Cyrus Wm. Rice Division
NUS Corporation, The Effects of Various Gas Atmospheres
On The Oxidation of Coal Mine Pyrites, Final Report,
FWQA Grant No. 14010 ECC, 1971

ABSTRACT:

A number of experiments up to 150 days in length were conducted to study the acid production rate of coal mine pyrites under various gas atmospheres. The gas atmospheres studied were air, nitrogen, methane, and carbon dioxide. The lower limits of the oxidation process were studied by introducing small amounts of oxygen along with the inert blanketing gas and by studying the effects of deaerated versus air saturated feedwater. Acid production was found to be proportional to the available oxygen partial pressure.

The acid parameters monitored continued to change and had not completely reached a steady state by the termination of the work. The acid production of nitrogen blanketed pyrite decreased to less than 1% of that of identical columns under an air atmosphere. Nitrogen and methane gases were equally effective in reducing acid production. Both of these gases were slightly more effective than carbon dioxide. A large amount of detailed experimental data is presented.

This report was submitted in fulfillment of Contract No. 14-12-877 between the Environmental Protection Agency, Water Quality Office and Cyrus Wm. Rice Division - NUS Corporation.

ACCESSION NO.

KEY WORDS:

Acid mine water
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1 Accession Number (X)	**2** Subject Field & Group OSG	**SELECTED WATER RESOURCES ABSTRACTS** **INPUT TRANSACTION FORM**

5 Organization

Environmental Protection Agency, Water Quality Office (Federal Office)
Cyrus Wm. Rice Division - NUS Corporation (Contractor)

6 Title

THE EFFECTS OF VARIOUS ATMOSPHERES ON THE OXIDATION OF COAL MINE PYRITES

10 Author(s) Robins, John D. Troy, Joseph C.	**16** Project Designation 14010 ECC 08/71 **21** Note

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*Acid mine water/*inert gas blanketing/*pyrite oxidation/*acid production/ *pyrite/water pollution control/water quality

25 Identifiers (Starred First)

*oxygen free atmospheres/mine drainage/pyrite depletion

27 Abstract

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Abstractor	Institution Cyrus Wm. Rice Division-NUS Corporation

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